SPIE. MEDICAL IMAGING

NEW LOCATION
20**15**
SEA WORLD

2015 TECHNICAL SUMMARIES.

WWW.SPIE.ORG/MI15

Conferences & Courses
21–26 February 2015

NEW LOCATION IN 2015
Renaissance Orlando at Sea World
Orlando, Florida, USA

2015 Symposium Chairs:

David Manning
Lancaster Univ.
(United Kingdom)

Steven C. Horii
The Univ. of
Pennsylvania Health
System (United States)

SPIE would like to express its deepest appreciation to the symposium chairs, conference chairs, program committees, session chairs, and authors who have so generously given their time and advice to make this symposium possible.

The symposium, like our other conferences and activities, would not be possible without the dedicated contribution of our participants and members. This program is based on commitments received up to the time of publication and is subject to change without notice.

COOPERATING ORGANIZATIONS

AAPM—American Association of Physicists
   in Medicine

APS—American Physiological Society

CARS—Computer Assisted Radiology and
   Surgery

MIPS—Medical Image Perception Society

RSNA—Radiological Society of North
   America

SIIM—Society for Imaging Informatics in
   Medicine

WMIS—World Molecular Imaging Society

The DICOM Standards Committee

PROMOTIONAL PARTNERS

BioPhotonics

MED Device Online

CREOL/Univ. of Central Florida

SILVER SPONSOR

ALIO 6-D

ALPINION
MEDICAL SYSTEMS

BRUKER **DESKCAT**
by modus

**Click on the Conference
Title to be sent to that page**

Conference 9412: Physics of Medical Imaging

Sunday - Wednesday 22–25 February 2015

Part of Proceedings of SPIE Vol. 9412 Medical Imaging 2015: Physics of Medical Imaging

9412-1, Session 1

The impact of imaging research on medicine and society: translating research into products *(Invited Paper)*

Norbert J. Pelc, Stanford Univ. (United States)

Innovations in diagnostic imaging have had important impact on medical practice and more importantly on individual patients. It provides valuable information that shortens the time to accurate diagnosis, reduces risk compared to more invasive alternatives, and improves patient management and outcomes. The impact of imaging research is multiplied if the advance is adopted by a large number of practitioners. This translation into wide use can be into the research community or into a much larger clinical base. While clinical adoption can reach more people research adoption may be very important by facilitating other advances that in turn get translated into broad use. Dissemination can be through publication of methods and results, which can be effective for research adoption, but broad dissemination very often requires incorporation into commercial products. The pathway to commercialization involves business decisions about the value to customers and marketing aspects which need to be weighed against the difficulties and costs of development, the availability of resources, both monetary and unique intellectual resources, and the difficulties and cost of regulatory approval. A decision to commercialize and idea is much more likely if the imaging advance has the support of stakeholders inside the company. For academic researchers this can be impacted by the degree to which the research has been collaborative with a company as opposed to being a new concept to the business. In this talk, I use a few vignettes to highlight these issues.

9412-2, Session 1

Complementary contrast media for metal artifact reduction in Dual-Energy CT

Jack Lambert, Univ. of California, San Francisco (United States); Peter M. Edic, Paul F. Fitzgerald, Andrew A. Torres, GE Global Research (United States); Benjamin M. Yeh, Univ. of California, San Francisco (United States)

Dual-Energy CT (DECT) has the capability of producing virtual monochromatic images, simulating how the data would appear if scanned at a single x-ray energy (keV). Monochromatic images representing a high energy are valuable because they greatly reduce the severity of metal artifacts. A problem with these high-keV images is that they also reduce the enhancement of currently-used contrast media. It is therefore impossible to generate monochromatic images with both high contrast and low artifact severity using currently-available contrast agents. Novel contrast agents based on higher atomic number (Z) elements, have the ability to maintain contrast enhancement at the higher keV levels where artifacts are reduced. This study evaluated three such candidate elements; bismuth, tantalum, and tungsten, as well as two conventional contrast elements: iodine and barium. A water-based phantom with vials containing these five elements in solution, as well as steel rods to produce artifacts, was scanned with a fast-kVp switching scanner using a standard, clinical DECT protocol. In the virtual monochromatic datasets, a 94% reduction in the contrast enhancement was observed for both iodine and barium, for the 140 keV images versus the 40 keV images. In comparison, the novel candidate agents demonstrated contrast enhancement reduction of 20% for tungsten, and 30% for both tantalum and bismuth, under the same conditions. Between the same images, metal artifact severity (standard deviation was reduced by 79%. Candidate agents containing high Z elements were thus shown to have an added benefit for imaging in patients where metal artifact reduction is needed.

9412-3, Session 1

Preliminary study of copper oxide nanoparticles acoustic and magnetic properties for medical imaging

Or Perlman, Technion-Israel Institute of Technology (Israel); Iris S. Weitz, ORT Braude College (Israel); Haim Azhari, Technion-Israel Institute of Technology (Israel)

The implementation of multimodal imaging in medicine is highly beneficial as different physical properties may provide complementary information, augmented detection ability, and diagnosis verification. Nanoparticles have been recently used as contrast agents for various imaging modalities. Their significant advantage over conventional large-scale contrast agents is the ability of detection at early stages of the disease, being less prone to obstacles on their path to the target region, and possible conjunction to therapeutics. Copper ions play essential role in human health. They are used as a co-factor for multiple key enzymes involved in various fundamental biochemistry processes. Extremely small size copper oxide nanoparticles (CuO-NPs) are readily soluble in water with high colloidal stability yielding high bioavailability.

The goal of this study was to examine the magnetic and acoustic characteristics of CuO-NPs in order to evaluate their potential to serve as contrast imaging agent for both MRI and ultrasound. CuO-NPs 7nm in diameter were synthesized by hot solution method. The particles were scanned using a 9.4T MRI and demonstrated a concentration dependent T1 relaxation time shortening phenomenon. In addition, it was revealed that CuO-NPs can be detected using the ultrasonic B-Scan imaging. Finally, speed of sound based ultrasonic computed tomography was applied and showed that CuO-NPs can be clearly imaged.

In conclusion, the preliminary results obtained, positively indicate that CuO-NPs may be imaged by both MRI and ultrasound. The results motivate additional in-vivo studies, in which the clinical utility of fused images derived from both modalities for diagnosis improvement will be studied.

9412-4, Session 1

Determination of contrast media administration to achieve a targeted contrast enhancement in CT

Pooyan Sahbaee, Yuan Lin, William P. Segars, Carl E.Ravin Advanced Imaging Labs., Duke Univ. (United States); Daniele Marin, Rendon Nelson, Duke Univ. (United States); Ehsan Samei, Carl E.Ravin Advanced Imaging Labs., Duke Univ. (United States)

The purpose of this study was to predict the required injection function to achieve a desired contrast enhancement in a given organ by incorporation of a physiologically based compartmental model. For a given injection protocol which reflects the concentration, duration, and rate of injection, the concentration and hence the distribution and propagation of contrast material can be patient-specifically estimated for different organs and vessels by applying computational pharmacokinetics and known physiologic patient-specific data. Two models were developed and evaluated. First, an iterative stripping model in which three steps were iteratively performed to deconvolve the target contrast enhancement into the injection function by applying the forward compartmental model to unity signal strips. Second, an analytical inverse model, i.e., an inverse computational compartmental model of cardiovascular system was designed, the solutions to which can provide the injection function. The two methods were evaluated in the context of five different target contrast enhancement functions for right heart, aorta, and kidney. The results exhibited that the two models offer

comparable performance with error in the range of 5% average deviation between the predicted and actual injection function. The findings enable the optimization of CT imaging not only in terms of image quality and dose but also the administration of proper injection protocol to achieve the best imaging at lowest radiation and contrast media dose. To our knowledge, this work is one of the first attempts to predict the contrast material injection function for a wanted organ enhancement curve up to date.

9412-5, Session 2

Application of a non-convex smooth hard threshold regularizer to sparse-view CT image reconstruction

Sean D. Rose, Emil Y. Sidky, Xioachuan Pan, The Univ. of Chicago (United States)

In this work, we apply non-convex, sparsity exploiting regularization techniques to image reconstruction in computed tomog- raphy (CT). We modify the well-known total variation (TV) penalty to use a non-convex smooth hard threshold (SHT) penalty as opposed to the typical l1 norm. The SHT penalty is different from the p < 1 norms in that it is bounded above and has bounded gradient as its argument approaches the zero vector. We propose a re-weighting scheme utilizing the Chambolle-Pock (CP) algorithm in an attempt to solve a data-error constrained optimization problem utilizing the SHT penalty and call the resulting algorithm SHTCP. We then demonstrate the algorithm on sparse-view reconstruction of a simulated breast phantom with noiseless and noisy data and compare the converged images to those generated by a CP algorithm solving the analogous data-error constrained problem utilizing the TV. We demonstrate that SHTCP allows for more accurate reconstruction in the case of sparse-view noisy data and, in the case of noiseless data, allows for accurate reconstruction from fewer views than its TV counterpart.

9412-6, Session 2

Cone-beam CT of traumatic brain injury using statistical reconstruction with a post-artifact-correction noise model

Hao Dang, Joseph W. Stayman, Alejandro Sisniega, Jennifer Xu, Wojciech Zbijewski, Johns Hopkins Univ. (United States); John Yorkston, Carestream Health, Inc. (United States); Nafi Aygun, Vassilis Koliatsos, Jeffrey H. Siewerdsen, Johns Hopkins Univ. (United States)

CT is the current front line imaging modality for detection of acute traumatic brain injury (TBI), providing reliable detection of intracranial hemorrhage (fresh blood contrast 30-50 HU, size down to 1 mm) in non-contrast-enhanced exams. We are developing flat-panel detector (FPD) cone-beam CT (CBCT) to facilitate such diagnosis in a low-cost, mobile platform suitable for point-of-care deployment. Such a system offers potential benefit in emergent, ambulance, sports, and military applications; however, the current generation of FPD-CBCT generally faces challenges that confound reliable low-contrast, soft-tissue imaging. Model-based reconstruction can improve image quality in soft-tissue imaging compared to conventional filtered backprojection (FBP) by leveraging high-fidelity forward model and sophisticated regularization. In FPD-CBCT TBI imaging, measurement noise characteristics undergo substantial change with artifact correction, resulting in non-negligible noise amplification. In this work, we extend the penalized weighted least-squares (PWLS) image reconstruction framework to include the two dominant artifact corrections (scatter and beam hardening) in FPD-CBCT TBI imaging by correctly modeling the variance change after each correction. Experiments were performed on a CBCT test-bench using an anthropomorphic phantom emulating intra-parenchymal hemorrhage in acute TBI, and the proposed method demonstrated an improvement in blood-brain contrast-to-noise ratio (CNR = 14.2) compared to FBP (CNR = 9.6) and PWLS without corrected weights (CNR = 11.6) at fixed

spatial resolution (1 mm edge-spread width at the target contrast). The results support the hypothesis that with high-fidelity artifact correction and statistical reconstruction with accurate post-artifact-correction noise models, FPD-CBCT can fulfill the image quality requirements for reliable detection of TBI.

9412-7, Session 2

Fat-constrained 18F-FDG PET reconstruction using Dixon MR imaging and the Origin Ensemble algorithm

Christian Wülker, Ruprecht-Karls-Univ. Heidelberg, Mannheim Medical Faculty (Germany); Susanne Heinzer, Philips AG Healthcare (Switzerland); Peter Börnert, Philips Research (Germany); Steffen Renisch, Philips Research (Germany); Sven Prevrhal, Philips Research (Germany)

Combined PET/MR imaging allows to incorporate the high-resolution anatomical information delivered by MRI into the PET reconstruction algorithm for improvement of PET accuracy beyond standard corrections. We used the working hypothesis that glucose uptake in adipose tissue is low. Thus, our aim was to shift 18F-FDG PET signal into image regions with a low fat content. Dixon MR imaging can be used to generate fat-only images via the water/fat chemical shift difference. On the other hand, the Origin Ensemble (OE) algorithm, a novel Markov chain Monte Carlo method, allows to reconstruct PET data without the use of forward- and backprojection operations. By adequate modifications to the Markov chain transition kernel, it is possible to include anatomical prior knowledge into the OE algorithm. In this work, we used the OE algorithm to reconstruct PET data of a modified IEC/NEMA Body Phantom simulating body water/fat composition. Reconstruction was performed 1) natively, 2) informed with the Dixon MR fat image to down-weight 18F-FDG signal in fatty tissue compartments in favor of adjacent regions, and 3) informed with the fat image to up-weight 18F-FDG signal in fatty tissue compartments, for control purposes. Image intensity profiles confirmed the visibly improved contrast and reduced partial volume effect at water/fat interfaces. We observed a 17 ± 2% increased SNR of hot lesions surrounded by fat, while image quality was almost completely retained in fat-free image regions.

9412-8, Session 2

Feasibility of CT-based 3D anatomic mapping with a scanning-beam digital x-ray (SBDX) system

Jordan M. Slagowski, Michael T. Tomkowiak, David A. P. Dunkerley, Michael A. Speidel, Univ. of Wisconsin-Madison (United States)

CT-derived anatomic maps can provide useful guidance during interventional procedures that involve the navigation of catheter devices to anatomic targets within cardiac chambers and large vessels. This study investigates the feasibility of obtaining CT-derived 3D surfaces from data provided by the scanning-beam-digital x-ray (SBDX) system. SBDX is a low-dose inverse geometry x-ray fluoroscopic system designed for cardiac procedures. In the proposed scheme, SBDX rotational acquisition is performed followed by inverse geometry CT reconstruction and segmentation of high contrast objects. Simulated scans of modified Shepp-Logan and thorax phantoms were performed for a 200 degree short scan arc with 180 gantry angles. Iterative reconstruction in 2D and 3D was implemented using a penalized weighted least squares objective function with total variation regularization (PWLS-TV) and without regularization (WLS). Voxel noise, edge blurring, and surface accuracy were evaluated, and compared to results obtained from a gridded filtered backprojection method. With the Shepp-Logan phantom, the relative root mean square error of the 3D iterative reconstruction was 1.4%. In the PWLS-TV nongated

reconstructions of a reduced-size thorax phantom with cardiac chamber, 95% of points on the segmented chamber perimeter were within 0.47, 0.70, and 1.26 mm of the ground truth, for fluences comparable to imaging through 17.3, 26.4, and 33.8 cm acrylic. Iterative reconstruction techniques may be adapted to irregular sinogram data in gated acquisitions. Results support the feasibility of 3D mapping of high contrast chambers from an SBDX rotational acquisition.

9412-9, Session 2

Clinical image benefits after model-based reconstruction for low dose dedicated breast tomosynthesis

Eri Haneda, J. Eric Tkaczyk, GE Global Research (United States); Giovanni J. Palma, Răzvan Iordache, Serge L. Muller, GE Healthcare (France); Bruno De Man, GE Global Research (United States)

Model-based iterative reconstruction (MBIR) is implemented to process full clinical data sets of dedicated breast tomosynthesis (DBT) in a low dose condition and achieves less spreading of anatomical structure between slices. MBIR is a regularized reconstruction method which can control trade-off between data fitting and image volume regularization. MBIR uses a cost optimization which integrates system data acquisition, photon statistics, and prior knowledge of reconstructed volume. MBIR has been successfully utilized in many imaging modalities including medical CT, PET, and transportation security CT.

In this study, anisotropic voxels are used to speed computation time in a manner consistent with the intrinsic spatial anisotropy associated with the limited view-angle. Additionally, regularization is formulated with anisotropic weighting that independently controls noise and resolution trade-offs among in-plane and out-of-plane voxel neighbors. Studies at partial and complete convergence show that the appropriate formulation of data-fit and regularization terms leads to a solution with improved localization of objects within a more narrow range of slices. This result is compared with the convergence of the solutions using simultaneous iterative reconstruction technique (SIRT). MBIR yields higher contrast-to-noise for diagnostic structures in the volumetric breast image and supports possible opportunity for dose reduction for 3D breast imaging. Analysis demonstrates the critical factors to these benefits for MBIR of clinical images are the appropriate weighting of the data fit term, balanced regularization between in-plane vs. out-of-plane and sufficient regularization to guarantee the convergence to a low noise solution.

9412-10, Session 2

Rank-sparsity constrained, spectro-temporal reconstruction for retrospectively gated, dynamic CT

Darin P. Clark, Duke Univ. Medical Ctr., Ctr. for In Vivo Microscopy (United States); Chang-Lung Lee, David G. Kirsch, Duke Univ. Medical Ctr. (United States); Cristian T. Badea, Ctr. for In Vivo Microscopy (United States)

Relative to prospective projection gating, retrospective acquisition and sorting of projection data for dynamic CT applications allows for fast imaging times which minimize the potential for physiological and anatomic variability. Preclinically, retrospective gating is attractive due to the rapid clearance of low molecular weight contrast agents and the rapid heart rate of rodents. Clinically, reconstruction from retrospectively gated projections is relevant for intraoperative C-arm CT. More generally, retrospective projection sampling provides an opportunity for significant x-ray dose reduction within the framework of compressive sensing theory and sparsity-constrained iterative reconstruction. Even so, CT reconstruction from projections with pseudo-random temporal sampling is a very poorly

conditioned inverse problem, requiring high fidelity regularization to minimize variability in the reconstruction results. Here, we introduce a highly novel regularization strategy for temporal CT reconstruction from retrospective projections which enforces local, spatio-temporal gradient sparsity to ensure consistency and global rank-sparsity to minimize artifacts caused by missing projection data. Furthermore, we show how the total number of retrospective projections can be split into subsets acquired at different energies to enable quantitative material decomposition with minimal impact on reconstruction quality. In this abstract, we show 4D simulation results (2D + 2 energies + time) using the proposed technique and compare them with two competing techniques—spatio-temporal total variation minimization and prior image constrained compressed sensing. We also introduce in vivo, 5D (3D + 2 energies + time) myocardial injury data acquired in a mouse on which we intend to demonstrate the proposed technique for the full conference paper.

9412-11, Session 3

Low-dose performance of wafer-scale CMOS-based X-ray detectors

Willem Maes, Inge M. Peters, Chiel Smit, Yves A. R. R. Kessener, Jan T. Bosiers, Teledyne DALSA (Netherlands)

Compared to amorphous-silicon (TFT) based X-ray detectors, CMOS active-pixel detectors exploit the benefits of low noise, high speed, on-chip integration and featuring offered by CMOS technology. This presentation focuses on the specific advantage of high image quality at very low dose levels.

The 15.3x15.3cm2 sized detector has 1548*1548 pixels, a FOP (fiber-optic plate) and a CsI scintillator. It uses 8-inch wafer-scale CMOS technology with 99x99μm2 pixels, low-noise readout, very low dark signal, highly linear response and high data bandwidth (72Mpxl/s). The design also supports instantaneous global selection between two pixel charge capacity modes: in low full well (LFW) mode, the detector is operating in High Sensitivity (HS) mode delivering the highest signal-per-photon level; while in high full well (HFW) mode, the detector operates in High Dynamic Range (HDR) mode with a five times increased exposure latitude. The on-chip 14 bit analog-to-digital conversion contributes to minimizing the readout noise, and this higher level of system integration is also beneficial for overall system cost and power consumption.

The detector performance at very low X-ray dose levels is presented, with a focus on DQE versus dose and spatial frequency, for both the HDR and HS modes; and on the Noise Equivalent Dose (NED). The good agreement obtained between the analytical model and measured values of DQE(f) and NED allows to predictably optimize the detector performance in the design phase to a wide range of application requirements.

9412-12, Session 3

Apodized-aperture pixel design to increase high-frequency DQE and reduce noise aliasing in x-ray detectors

Ian A. Cunningham, Robarts Research Institute (Canada) and Western Univ. (Canada); Elina Ismailova, Western Univ. (Canada); Karim S. Karim, Univ. of Waterloo (Canada)

The detective quantum efficiency (DQE) of an x-ray detector, expressed as a function of spatial frequency, describes the ability to produce high-quality images relative to an ideal detector. Some detectors, in particular Se-based systems, have substantial levels of noise aliasing that can reduce the high-frequency DQE by 50% or more and give a high-frequency appearance to image noise. While some technologies (eg. CMOS) can now be manufactured with very small detector elements (eg. 25 μm), the resulting images may be too large for display or routine transmission and archival in most clinical settings. We are investigating the use of 25-μm detector elements to synthesize larger 100-μm pixels with an anti-aliasing

filter that eliminates most noise aliasing. When used with a high-resolution x-ray converter such as Se, the result is a 100-μm pixel detector with a doubling of the high-frequency DQE. We present the theoretical basis of what we call an apodized-aperture pixel structure. A cascaded-systems analysis is performed to describe the resulting DQE. It is shown theoretically that the high-frequency DQE of a Se-based detector can be doubled and experimentally that a CMOS-based CsI system is increased by 30%. We propose a scenario where small physical detector elements are used routinely to synthesize larger elements as a method of increasing the high-frequency DQE in medical radiography.

9412-13, Session 3

Low dose digital X-ray imaging with avalanche amorphous selenium

James R. Scheuermann, Amir H. Goldan, Yesenia Miranda, Hongyu Liu, Stony Brook Univ. (United States); Olivier Tousignant, Sébastien Léveillé, Analogic Canada Corp. (Canada); Wei Zhao, Stony Brook Univ. (United States)

A large area flat panel imager is being developed for low dose x-ray imaging. Quantum noise limited imaging can be achieved by the use of avalanche multiplication of photogenerated charge prior to readout by a thin film transistor (TFT) array. This eliminates the effects of electronic noise associated with the readout electronics. Signal amplification is accomplished through the use of a thin layer of avalanche amorphous selenium (a-Se) called High Gain Avalanche Rushing Photoconductor (HARP). We have developed the first large area HARP structure with reliable gain of 80, suitable for deposition onto a TFT array. This required the development of new fabrication processes and a new hole-blocking layer to prevent breakdown of a-Se at electric fields greater than 70Vμm-1, which are required to produce avalanche gain. Additionally, we have investigated tunable mobility of the primary charge carriers in the blocking layers to incorporate the defect suppression effects of a distributed resistive layer (DRL). Optimization of the mobility can reduce dark current and Joule heating at localized defects to prevent re-crystallizing of the a-Se. Numerical simulation of charge transport in the new HARP structure has shown a reduction of dark current by ~2 orders of magnitude with the incorporation of a DRL. Experimental results have shown that doped organic blocking layers can have mobility that span four orders of magnitude, satisfying the requirements set forth by the simulation.

9412-14, Session 3

Multi-energy imagers for a radiotherapy treatment environment

Larry E. Antonuk, Langechuan Liu, Albert K. Liang, Youcef El-Mohri, Qihua Zhao, Martin Koniczek, Hao Jiang, Univ. of Michigan (United States)

Over the last ~15 years, the central goal in external beam radiotherapy of maximizing dose to the tumor while minimizing dose to surrounding normal tissues has been greatly facilitated by development and clinical implementation of many innovations. These include flat-panel digital detectors designed to image the megavoltage beam from the treatment machine, and separate digital detectors and x-ray sources designed to provide high-contrast, cone-beam CT images. While these systems provide clinically valuable information, a variety of advantages would accrue through the introduction of a single detector capable of providing information at different energies. One possible approach involves merging current megavoltage and kilovoltage imaging systems through introduction of a diagnostic-quality x-ray source into the treatment head along with consolidation of megavoltage and diagnostic x-ray detection into a single, dual-energy detector. Such integration would eliminate the geometric uncertainties associated with registering kV and MV images, reduce the effort required for quality assurance, reduce encumbrances in the vicinity

of the gantry treatment position, and greatly decrease equipment costs. A second approach involves introduction of a large area, monolithic array of single-photon-counting pixels with multiple energy binning capability, which would result in improved image contrast at lower dose. In this presentation, the merits of each approach will be outlined and a detailed, quantitative examination of the performance of various dual-energy imager designs will be presented. Finally, the anticipated technical and performance capabilities of single photon counting arrays designed for the radiotherapy environment will be discussed. The research was partially supported by NIH grant R01-EB000558.

9412-15, Session 3

Investigation of the screen optics of thick CsI(Tl) detectors

Adrian F. Howansky, Boyu Peng, Stony Brook Univ. (United States); Katsuhiko Suzuki, Masanori Yamashita, Hamamatsu Photonics K.K. (Japan); Anthony R. Lubinsky, Wei Zhao, Stony Brook Univ. (United States)

Flat panel imagers (FPI) are becoming the dominant detector technology for digital x-ray imaging. In indirect FPI, the scintillator that provides the highest image quality is Thallium (Tl) doped Cesium Iodide (CsI) with columnar structure. The maximum CsI thickness used in existing FPI is ~600 microns, due to concerns of loss in spatial resolution and light output with further increase in thickness. The goal of the present work is to investigate the screen-optics for CsI with thicknesses much larger than that used in existing FPI, so that the knowledge can be used to improve imaging performance in dose sensitive and higher energy applications, such as cone-beam CT (CBCT). Columnar CsI(Tl) scintillators up to 1 mm in thickness with different screen-optical design were investigated experimentally. Pulse height spectra (PHS) were measured to determine the Swank factor at x-ray energies between 25 and 75 keV, and to derive depth-dependent light escape efficiency i.e. gain. Detector presampling MTF, NPS and DQE were measured using a high-resolution CMOS optical sensor. Optical Monte Carlo simulation was performed to estimate optical parameters for each screen design, derive depth-dependent gain and MTF, and yield agreement with measured MTF and DQE. These depth-dependent imaging performance parameters were then used in a cascaded linear system model (CLSM) to investigate detector performance under front- and back-irradiation conditions. The methodology developed for understanding the screen optics of thick CsI(Tl) will lead to detector optimization in CBCT.

9412-16, Session 4

New signal extraction method to enable single exposure data acquisitions in grating-based multi-contrast imaging system without mechanical phase stepping and object translation

Yongshuai Ge, John W. Garrett, Ke Li, Guang-Hong Chen, Univ. of Wisconsin-Madison (United States)

In a grating interferometer-based x-ray differential phase contrast (DPC) imaging system, an analyzer grating (i.e. G2 grating) is sequentially marched through several steps (i.e., phase stepping) to acquire the needed multiple intensity measurements to extract phase contrast and dark field signals, in additional to the absorption signal. The need of mechanical phase stepping significantly prolongs the data acquisition time and thus hinders the potential utility of the methods in practice. Recently, several methods have been proposed to eliminate the motion of the either the movements of one of the gratings or the image object. This includes a new staggered grating design and a Fourier domain moiré pattern analysis method. The Fourier domain moiré pattern analysis method uses a tilted conventional one-dimensional collinear G2 grating, and a Fourier domain

low-pass filter operation is needed to extract the signals and thus results in a degradation in spatial resolution for all the three contrast mechanisms. In this work, we present a new signal extraction method, in which the extract differential phase and dark field images from moiré pattern only lose spatial resolution along one direction, and most importantly, this proposed method successfully avoided the spatial resolution degradation in absorption image.

9412-17, Session 4

Phase-contrast x-ray imaging and Compton scattering at 120 keV

Matteo Abis, Paul Scherrer Institut (Switzerland) and ETH Zurich (Switzerland); Zhentian Wang, Paul Scherrer Institut (Switzerland); Marco F. M. Stampanoni, ETH Zurich (Switzerland) and Paul Scherrer Institut (Switzerland)

Grating interferometry is an imaging technique that allows the simultaneous retrieval of attenuation, phase and small angle scattering of x-rays. It was first demonstrated on synchrotron sources, then applied to conventional sources with a wide bremsstrahlung spectrum and low spatial coherence. Experiments on lab sources have been performed only for energies below 60 keV, while most applications in medicine and nondestructive testing require higher penetration power, with voltages above 100 kV. Absorption gratings suitable for high-energy interferometers would require a large thickness and a small pitch, in order to provide both enough blocking power and sensitivity. The necessary aspect ratios are thus outside of the reach of the most advanced microfabrication techniques. An edge-on arrangement of the gratings is presented, where the gratings are not illuminated on the face but lay down in the beam plane, so that arbitrarily high aspect ratios can be achieved at the cost of one spatial dimension. With such an alignment, it is also easy to build curved structures that match the beam divergence on short setups. The design of this kind of setup is shown, as well as the first images taken with two prototypes with a design energy of 100 and 120 keV realized at PSI. Experimental data from different materials allow to link Compton scattering and transmission in this energy range. The retrieval and meaning of the attenuation, differential phase and scattering signals is discussed, together with the possible applications available in this new energy range.

9412-18, Session 4

Phase-contrast imaging using radiation sources based on laser-plasma wakefield accelerators: state of the art and future development

David Reboredo Gil, Silvia Cipiccia, Peter A. Grant, Gregor H. Welsh, David William Grant, Graeme McKendrick, Univ. of Strathclyde (United Kingdom); Anna Subiel, National Physical Lab. (United Kingdom); Dima Maneuski, Univ. of Glasgow (United Kingdom); Samuel M. Wiggins, Dino A. Jaroszynski, Univ. of Strathclyde (United Kingdom)

Both laser-plasma wakefield acceleration (LWFA) and X-ray phase-contrast imaging (PCi) are promising technologies that are attracting the attention of the scientific community. Conventional X-ray absorption imaging cannot be used as a means of imaging biological material because of low contrast. PCi overcomes this limitation by exploiting the variation of the refraction index of materials. The contrast obtained is higher than for conventional absorption imaging and requires a lower dose. LWFA is a new concept of acceleration where electrons are accelerated to very high energy (~150 MeV) in very short distances by surfing plasma waves excited by the passage of a ultra-intense laser (~1018 Wcm-2) through plasma. Electrons in the LWFA can undergo transverse oscillation and emit synchrotron-like radiation (betatron radiation2,3) in a narrow cone along the propagation axis. The properties of the betatron radiation produced by LWFA, such as source

size and spectrum, make it a good candidate for X-ray PCi. In this work we present the characterization of betatron radiation produced by the LWFA in the ALPHA-X laboratory (at the University of Strathclyde). We show how phase contrast images can be obtained using the betatron radiation in a free space propagation configuration and we discuss the potential and limitation of LWFA driven X-ray PCi.

9412-19, Session 4

Laboratory implementation of edge illumination X-ray phase-contrast imaging with energy-resolved detectors

Paul C. Diemoz, Marco Endrizzi, Fabio A. Vittoria, Charlotte K. Hagen, Univ. College London (United Kingdom); Gibril Kallon, Dario Basta, Univ College London (United Kingdom); Massimo Marenzana, Kennedy Institute of Rheumatology, Univ. of Oxford (United Kingdom); Pasquale Delogu, Istituto Nazionale di Fisica Nucleare (Italy); Alessandro Vincenzi, PIXIRAD Imaging Counters s.r.l. (Italy); Luca De Ruvo, Istituto Nazionale di Fisica Nucleare (Italy); Gloria Spandre, Alessandro Brez, Ronaldo Bellazzini, Istituto Nazionale di Fisica Nucleare (Italy) and PIXIRAD Imaging Counters s.r.l. (Italy); Alessandro Olivo, Univ. College London (United Kingdom)

The Edge illumination (EI) X-ray phase-contrast imaging (XPCI) technique has emerged in recent years as a powerful technique for the investigation of samples in a broad range of fields. In particular, EI was proven to combine high phase sensitivity with practical applicability using conventional X-ray sources [1-3]. In this talk, we will focus on the modelling of the technique through the use of geometrical optics, showing that, in laboratory implementations, this provides results matching those of rigorous wave optics calculations. This originates from the fact that EI is an intrinsically incoherent method, which does not rely on coherent wave effects and is indeed resilient to both broad beam polychromaticity and to the use of extended focal spots [3]. Simple expressions have been derived, which relate the spatial resolution and phase sensitivity to the used experimental parameters. These will be exploited to highlight the effect of the different parameters on the signal, and to propose possible strategies for setup optimization. Finally, recent results obtained with the use of EI in combination with PIXIRAD, a photon-counting, energy-resolved detector, will be presented. These measurements take full advantage of the achromaticity of the EI setup (meaning that all energies in the spectrum contribute to the image contrast), by using this additional energy information to further enhance the image quality.

[1] A. Olivo and R. D. Speller, APL 91(7), 074106 (2007)

[2] P. C. Diemoz, et al., PRL 110(13), 138105 (2013).

[3] P. C. Diemoz, et al., APL 103(24), 244104 (2013).

9412-20, Session 4

Small animal functional lung imaging via parametric x-ray phase-contrast imaging

Alfred B. Garson III, Washington Univ. in St. Louis (United States); Sunil Vasireddi, MetroHealth Medical Ctr., Case Western Reserve Univ. (United States) and Washington Univ. in St. Louis (United States); Sean Gunsten, Mallinckrodt Institute of Radiology, Washington Univ. in St. Louis (United States); Huifeng Guan, Steven L. Brody, Washington Univ. in St. Louis (United States); Mark A. Anastasio, Washington Univ. in St. Louis (United States) and Mallinckrodt Institute of Radiology (United States)

We demonstrate a novel X-ray phase-contrast (XPC) method for dynamic functional lung imaging that represents a paradigm shift in the way small animal functional imaging is performed. In our method, information regarding airway microstructure that is encoded within speckle texture of a single XPC ra- diograph is decoded to produce 2D parametric images. These parametric images will spatially resolve changes in lung properties such as microstructure sizes, air volumes, and compliance, to name a few. Such functional information cannot be derived from conventional lung radiography or any other 2D imaging modality. By computing these images at different time points within a breathing cycle, dynamic func- tional imaging will be readily achieved without the need for tomography.

9412-21, Session 4

Enabling lower dose scans by redefining the lower statistical limit in X-ray phase-contrast computed tomography

Mathias Marschner, Michael Chabior, Andreas Fehringer, Peter B. Noël, Franz Pfeiffer, Technische Univ. München (Germany)

Phase-contrast X-ray computed tomography (PCCT) is currently investigated and developed as a potentially very interesting extension of conventional CT, because it promises to provide high soft-tissue contrast for weakly absorbing samples. For data acquisition several images at different grating positions are combined to obtain a phase-contrast projection. For short exposure times, which are necessary for lower radiation dose, the photon counts in a single stepping position are very low. In this case, the currently used phase-retrieval does not provide reliable results for some pixels. This uncertainty results in statistical phase wrapping, which leads to a higher standard deviation in the phase-contrast projections than theoretically expected. For even lower statistics, the phase retrieval breaks down completely and the phase information is lost. New measurement procedures rely on a linear approximation of the sinusoidal phase stepping curve around the zero crossings. In this case only two images are acquired to obtain the phase-contrast projection. The approximation is only valid for small phase values. However, typically nearly all pixels are within this regime due to the differential nature of the signal. We examine the statistical properties of a linear approximation method and illustrate by simulation and experiment that the lower statistical limit can be redefined using this method. That means that the phase signal can be retrieved even with very low photon counts and statistical phase wrapping can be avoided. This is an important step towards enhanced image quality in PCCT with very low photon counts.

9412-214, Session WK1

Quantifying and reducing uncertainties in cancer therapy

Harrison H. Barrett, David S. Alberts, James M. Woolfenden, Zhonglin Liu, Lars R. Furenlid, The Univ. of Arizona (United States)

There are two basic sources of uncertainty in cancer chemotherapy: how much of the therapeutic agent reaches the cancer cells, and how effective it is in reducing or controlling the tumor when it gets there.

There is also a concern about adverse effects of the therapy drug. Similarly in external-beam radiation therapy or radionuclide therapy, there are two levels of uncertainty: delivery and efficacy of the radiation absorbed dose, and again there is a concern about radiation damage to normal tissues. The therapy operating characteristic (TOC) curve, developed in the context of radiation therapy, is a plot of the probability of tumor control vs. the probability of normal-tissue complications as the overall radiation dose level is varied, e.g. by varying the beam current in external-beam radiotherapy or the total injected activity in radionuclide therapy. The TOC can be applied to chemotherapy with the administered drug dosage as the variable. The

area under a TOC (AUTOC) can be used as a figure of merit for therapeutic efficacy, analogous to the area under an ROC curve (AUROC), which is a figure of merit for diagnostic efficacy. In radiation therapy AUTOC can be computed for a single patient by using image data along with radiobiological models for tumor response and adverse side effects. In this paper we will discuss the potential of using mathematical models of drug delivery and tumor response along with imaging data to estimate AUTOC for chemotherapy, again for a single patient. Uncertainties in the estimates will be discussed.

9412-22, Session 5

Optimization and image quality assessment of the alpha-image reconstruction algorithm: iterative reconstruction with well-defined image quality metrics

Sergej Lebedev, Stefan Sawall, Deutsches Krebsforschungszentrum (Germany); Stefan Kuchenbecker, Sebastian Faby, German Cancer Research Center (DKFZ) (Germany); Michael Knaup, Marc Kachelriess, Deutsches Krebsforschungszentrum (Germany)

Reconstructing CT images with low noise and high spatial resolution is challenging. Iterative reconstruction promises to be a good solution. Conventional iterative approaches suffer from a lack of well-defined image quality metrics, e.g. the modulation transfer function (MTF), and from inadequate noise textures. To overcome this issue we recently proposed a novel reconstruction scheme, the alpha-image reconstruction (AIR). Here we aim at improving AIR's computational performance and to quantify AIR's image quality. AIR uses a set of basis images, e.g. two or more FBP reconstructions with different reconstruction kernels. AIR reconstructs voxel-wise weighting images, the alpha images, that are used to blend between the basis images. The result is an image of high diagnostic quality containing formerly mutual exclusive image characteristics. This will be illustrated using simulated and measured data. The resulting MTF is compared to the basis images and to a penalized weighted least-squares reconstruction. While the MTF is undefined for the latter, we demonstrate that the MTF in the AIR images is well-defined. It is the linear combination of the MTFs found in the basis images. The proposed optimization strategies increase AIR's computational performance by a factor of 10 compared to a straight forward implementation. Although still slower than a filtered backprojection AIR is now in the computational range of typical iterative image reconstruction algorithms. In addition to AIR's high image quality it is also possible to specify classical image quality measures such as the MTF, the PSF, the SSP, and image noise on a voxel-specific basis.

9412-23, Session 5

An example-based brain MRI simulation framework

Qing He, Henry M. Jackson Foundation for the Advancement of Military Medicine (United States); Snehashis Roy, Henry M. Jackson Foundation (United States); Amod Jog, Johns Hopkins Univ. (United States); Dzung L. Pham, Henry M. Jackson Foundation (United States)

The simulation of magnetic resonance (MR) images plays an important role in the validation of image analysis algorithms due to lack of sufficient ground truth in real MR images. Previous work on MRI simulation has focused on explicitly modeling the MR image formation process. However, because of the overwhelming complexity of MR acquisition these

simulations must involve simplifications and approximations that can result in visually unrealistic simulated images. In this work, we describe an example-based simulation framework, which uses an "atlas" consisting of an MR image and its anatomical models (segmentations). The relationships between the MR image intensities and its anatomical models are learned using a patch-based regression that implicitly models the physics of the MR image formation. Given a new anatomical model, a new MR image can be simulated using the learned regression. This approach has been extended to also simulate intensity inhomogeneity artifacts. Results show that the example based MRI simulation method is capable of simulating different image contrasts and is robust to different choices of atlas.

9412-24, Session 5

Motion estimation and compensation for coronary artery and myocardium in cardiac CT

Qiulin Tang, Toshiba Medical Research Institute USA (United States); James Matthews, Marco Razeto, Toshiba Medical Visualization Systems Europe, Ltd. (United Kingdom); Jesper J Linde, Department of Cardiology, University of Copenhagen (Denmark); Satoru Nakanishi, Toshiba Medical Research Institute USA (United States)

Motion blurring is still a challenge for cardiac CT imaging. A new motion estimation (ME) and motion compensation method is developed for cardiac CT. The proposed method estimates motion of entire heart, and then applies motion compensation. Therefore, the proposed method reduces motion artifacts not only in coronary artery region as most other methods did, but also reduces motion blurring in myocardium region. In motion compensated reconstruction, we use Fourier transfer method proposed by Pack et al to obtain a series of partial images, and then warp and sum together to obtain final motion compensated image. The robustness and performance of the proposed method was verified with 10 patient data and improvements in sharpness of both coronary arteries and improvement in myocardium region were obtained.

9412-25, Session 5

Estimating ROI activity concentration with photon-processing and photon-counting SPECT systems

Abhinav K. Jha, Eric C. Frey, Johns Hopkins Univ. (United States)

Recently a new class of imaging systems, referred to as photon-processing systems, are being developed that uses real-time maximum-likelihood (ML) methods to estimate multiple attributes per detected photon and store these attributes in a list format. PP systems could have a number of potential advantages compared to systems that bin photons based on attributes such as energy, projection angle, and position, referred to as photon-counting (PC) systems. For example, PP systems do not suffer from binning-related information loss and provide the potential to extract information from attributes such as energy deposited by the detected photon. However, noise effects may offset these advantages. Thus, objective evaluation studies are required to determine the conditions in which PP systems offer improved performance compared to PC systems. We are performing this study in the context of quantitative 2-dimensional single-photon emission computed tomography (SPECT) imaging, where the end task is estimating the mean activity concentration within a region of interest (ROI). We first theoretically outline the effect of null space on estimating the mean activity concentration, and argue that due to this effect, PP systems could have better estimation performance compared to PC systems with noise-free data. To evaluate the performance of PP and PC systems with noisy data, we developed a singular value decomposition

(SVD)-based analytic method to estimate the activity concentration from PP systems. Using simulations implemented on graphics processing units (GPUs), we studied the accuracy and precision of this technique in estimating the activity concentration. We used this framework to objectively compare PP and PC systems on the activity concentration estimation task. We investigated the effects of varying the size of the ROI and varying the number of bins for the attribute corresponding to the angular orientation of the detector in a continuously rotating SPECT system. The results indicate that in most cases, PP systems offer improved estimation performance compared to PC systems.

9412-26, Session 5

Monte Carlo simulation of inverse geometry x-ray fluoroscopy using a modified MC-GPU framework

David A. P. Dunkerley, Michael T. Tomkowiak, Jordan M. Slagowski, Univ. of Wisconsin-Madison (United States); Bradley P. McCabe, The Univ. of Chicago (United States); Tobias Funk, Triple Ring Technologies, Inc. (United States); Michael A. Speidel, Univ. of Wisconsin-Madison (United States)

The Scanning-Beam Digital X-ray (SBDX) system is a technology for low-dose fluoroscopy that employs inverse geometry x-ray beam scanning. To assist with rapid optimization and evaluation of inverse geometry x-ray systems, we have developed a Monte Carlo (MC) simulation tool based on the MC-GPU framework. MC-GPU code was modified to implement a 2D array of focal spot positions on a plane, with individually adjustable x-ray outputs, each producing a narrow x-ray beam directed toward a stationary photon-counting detector array. Geometric accuracy was evaluated by simulating imaging of a 3D arrangement of spheres and comparing reconstructions of the detector images to the phantom geometry. Detected x-ray scatter fraction for acrylic phantoms was simulated for two SBDX detector geometries and compared to experiments. For the current SBDX prototype (10.6 cm wide by 5.3 cm tall detector), x-ray scatter fraction measured 2.8-6.4% (18.6-31.5 cm), versus 2.2-5.0% in MC simulation. Experimental trends in scatter versus detector size and phantom thickness were observed in simulation. For dose evaluation, an anthropomorphic phantom was imaged using regular and regional adaptive exposure (RAE) scanning. The imaging scenarios were then reproduced in simulation. The reduction in kerma-area-product resulting from RAE scanning was 45% in film measurements, versus 46% in simulation. The integral dose calculated from TLD measurement points within the phantom was 57% lower when using RAE, versus 61% lower in simulation. This MC tool may be used to estimate scatter and dose distributions when developing inverse geometry x-ray systems.

9412-27, Session 6

Image-based material decomposition with a general volume constraint for photon-counting CT

Zhoubo Li, Shuai Leng, Lifeng Yu, Cynthia H. McCollough, Mayo Clinic (United States)

Photon-counting CT (PCCT) potentially offers both improved dose efficiency and material decomposition capabilities relative to CT systems using energy integrating detectors. With respect to material decomposition, both projection-based and image-based methods have been proposed, most of which require accurate a priori information regarding the shape of the x-ray spectra and the response of the detectors. Additionally, projection-based methods require access to projec-tion data. These data can be difficult to obtain, since spectra, detector response, and projection data formats are proprietary information. Further, some published image-based, 3-material

decomposition methods require a volume conservation assumption, which is often violated in solutions. We have developed an image-based material decomposition method that can overcome those limitations. We introduced a general condition on volume constraint that does not require the volume to be conserved in a mixture. An empirical calibration can be performed with various concentrations of basis materials. The material decomposition method was applied to images acquired from a prototype whole-body PCCT scanner. The results showed good agreement between the estimation and known mass concentration values. Factors affecting the performance of material decomposition, such as energy threshold configuration and volume conservation constraint, were also investigated. Changes in accuracy of the mass concentration estimates were demonstrated for four different energy configurations and when volume conservation was required.

9412-28, Session 6

Fluence Feld modulated CT on a clinical TomoTherapy Radiation Therapy machine

Timothy P. Szczykutowicz, James R. Hermus, Univ. of Wisconsin-Madison (United States)

Purpose: The multi-leaf collimator assembly present on TomoTherapy (Accuray, Madison WI) radiation therapy (RT) and mega voltage CT machines is well suited to perform fluence field modulated CT (FFMCT). In addition, there is a demand in the RT environment for FFMCT imaging techniques, specifically volume of interest (VOI) imaging. This paper demonstrates that FFMCT can be performed using the multi-leaf-collimators on a clinical TomoTherapy machine for the first time. Methods: A clinical TomoTherapy machine was programmed to deliver 20% imaging dose outside a predefined VOI. Projections intersecting the VOI received "full dose" while those not intersecting the VOI received 20% of the dose (i.e. the incident fluence for non VOI projections was 20% of the incident fluence for projections intersecting the VOI). Scans were also acquired un-modulated at 20% and "full dose". The noise (pixel standard deviation) was measured inside the VOI region and compared between the three scans. Results: The VOI-FFMCT technique produced an image noise 1.12 times higher than the full dose" scan, while the 20% dose scan produced a noise level 2.63 times higher than the "full dose" scan.

Conclusions: Noise levels can be almost unchanged within clinically relevant VOIs for RT applications while the integral imaging dose to the patient can be decreased, and or the image quality in RT can be dramatically increased with no change in dose relative to non-FFMCT RT imaging. The ability to shift dose from regions clinicians do not care about to those that they do improves image quality.

9412-29, Session 6

Dual-energy imaging of bone marrow edema on a dedicated multi-source cone-beam CT system for the extremities

Wojciech Zbijewski, Alejandro Sisniega, Joseph W. Stayman, Gaurav Thawait, Johns Hopkins Univ. (United States); Nathan Packard, John Yorkston, Carestream Health, Inc. (United States); Shadpour Demehri, Jan Fritz, Jeffrey H. Siewerdsen, Johns Hopkins Univ. (United States)

Purpose: Arthritis and bone trauma are often accompanied by bone marrow edema (BME). BME is challenging to detect in CT due to the overlaying trabecular structure but can be visualized using Dual Energy (DE) techniques to discriminate water and fat. We investigate the feasibility of DE imaging of BME on a dedicated flat-panel detector (FPD) extremities cone-beam CT (CBCT) with a unique x-ray tube with three longitudinally mounted sources.

Methods: Simulations involved a digital BME knee phantom imaged with a 60 kVp low energy beam (LE) and 105 kVp high energy beam (HE) (+0.25

mm Ag filter). Experiments were also performed on a test-bench with a Varian 4030CB FPD using the same beam energies as the simulation study. A three-source DE acquisition orbit whereby the superior and inferior sources operate at HE (and collect half of the projection angles each) and the central source operates at LE was compared to a double-scan, single-source orbit. A bone phantom (trabeculae down to ~1 mm) submerged in alcohol (simulating fat) was used to emulate the trabecular matrix. Reconstruction-based three-material decomposition of fat, soft tissue, and bone was performed.

Results: For a low-dose scan (36 mAs in the HE and DE data), DE CBCT achieved combined accuracy of ~0.8 for a BME pattern of 10 - 2.5 mm spheres in the knee phantom. The accuracy increased to ~0.9 for a 360 mAs scan. Excellent DE discrimination of the base materials was achieved in the experiments. Approximately 80% of the alcohol (fat) voxels in the bone phantom was properly identified both for single and 3-source acquisitions.

Conclusion: Detection of BME and quantification of water and fat content were achieved in extremities DE CBCT with a longitudinal configuration of sources providing DE imaging in a single gantry rotation. The findings enable application of extremities CBCT in areas conventionally in the domain of MRI.

9412-30, Session 6

Initial results from a prototype whole-body photon-counting computed tomography system

Zhicong Yu, Shuai Leng, Steven M. Jorgensen, Zhoubo Li, Mayo Clinic (United States); Ralf Gutjahr, Siemens Medical Solutions (United States); Baiyu Chen, Mayo Clinic (United States); Xinhui Duan, The Univ. of Texas Southwestern Medical Ctr. at Dallas (United States); Ahmed Halaweish, Siemens Medical Solutions (United States); Lifeng Yu, Erik L. Ritman, Cynthia H. McCollough, Mayo Clinic (United States)

X-ray computed tomography (CT) with energy-discriminating capabilities presents exciting opportunities for increased dose efficiency and improved material decomposition analyses. However, due to constraints imposed by the inability of photon-counting detector's (PCD) respond accurately at high photon fluence rates, to date there has been no clinical application of PCD-CT. Recently, our lab installed a research prototype system consisting of two x-ray sources and two corresponding detectors, one using an energy-integrating detector (EID) and the other using a PCD. In this work, we report the first third-party evaluation of this prototype system using both phantom and cadaveric objects. The phantom studies demonstrated several promising characteristics of the PCD sub-system, including improved contrast-to-noise ratio (CNR) and reduced beam hardening artifacts, relative to the EID sub-system. More importantly, we found that the PCD offers excellent pulse pileup control in cases of high x-ray fluence rates up to 550 mAs at 140 kV, which corresponds to approximately $2.5*10^{11}$ photons per cm^2 per second. In an anthropomorphic phantom and the cadaveric head, the PCD sub-system provided image quality comparable to the EID sub-system for the same dose level. Our results demonstrate the potential of the prototype system to produce clinically-acceptable images in vivo.

9412-31, Session 6

Fluid dynamic bowtie attenuators

Timothy P. Szczykutowicz, James R. Hermus, Univ. of Wisconsin-Madison (United States)

Purpose: Fluence field modulated CT allows for improvements in image quality and dose reduction. To date, only 1-D modulators have been proposed, the extension to 2-D modulation is difficult with metal filter modulators. This work proposes to use liquids and gas modulators which

can be arrayed allowing for 2-D fluence modulation. Materials and Methods: The thickness of liquid and the pressure for a given path length of gas were determined that provided the same attenuation as 30 cm of soft tissue at 80, 100, 120, and 140 kV. Gaseous Xenon and liquid Iodine, Zinc Chloride, and Cerium Chloride were studied. Additionally, we performed some proof-of-concept experiments in which (1) a single cell of liquid was connected to a reservoir which allowed the liquid thickness to be modulated and (2) a 96 cell array was constructed in which the liquid thickness in each cell was adjusted manually. Results: Liquid thickness varied as a function of kV and chemical composition, with Zinc Chloride allowing for the smallest thickness; 1.8, 2.25, 3, and 3.6 cm compensated for 30 cm of soft tissue at 80, 100, 120, and 140 kV respectively. The 96 cell Iodine attenuator allowed for a reduction in dynamic range to the detector and scatter to primary ratio. Successful modulation of a single cell was performed at 0, 90, and 130 degrees using a simple piston/actuator. Conclusions: The thickness of liquids and the Xenon gas pressure seem logistically implementable within the constraints of CBCT and diagnostic CT systems.

9412-32, Session 6

A new CT system architecture for high temporal resolution with applications to improved geometric dose efficiency and sparse sampling

Guy M. Besson, ForeVision Technologies (United States)

A new CT system architecture is introduced with the potential to achieve significantly higher temporal resolution than is currently possible with current medical imaging CT. The concept relies only on known technologies; in particular rotation speeds several times higher than what is possible today could be achieved leveraging typical x-ray tube designs and capabilities. The new CT architecture is constituted of the following elements: (1) decoupling of the source rotation from the detector rotation; (2) observation of a source at a range of azimuthal angles with respect to a given detector cell; (3) utilization of a multiplicity of x-ray sources; (4) use of a wide-angle iso-centered detector mounted on an independent detector gantry or drum; (5) the detector drum presents a wide angular aperture allowing x-rays from the various sources to pass through, with the active detector cells occupying about 240-degrees, and the wide aperture the complementary 120-degrees; (6) anti-scatter grids with absorbing lamellas oriented substantially parallel to the main gantry plane. With these elements, acquisition of complete data for a given trans-axial slice could be achieved in 40 milliseconds or less, while delivering an x-ray exposure commensurate with that delivered by a system acquiring complete data in 200 milliseconds. Application to the design of a CT system with nearly 100% geometric dose efficiency is described. Further, the architecture enables the acquisition of sparse data in specific patterns termed "view bunching." View bunching in turn has the potential to yet further increase the temporal resolution achievable for specific applications.

9412-33, Session 7

Spectral CT of the extremities with a silicon strip photon counting detector

Alejandro Sisniega, Wojciech Zbijewski, Joseph W. Stayman, Jennifer Xu, Dongjie Xie, Katsuyuki Taguchi, Johns Hopkins Univ. (United States); Erik Fredenberg, Mats Lundqvist, Philips Women's Heatlhcare (Sweden); Jeffrey H. Siewerdsen, Johns Hopkins Univ. (United States)

Purpose: Photon counting x-ray detectors (PCXDs) are an important emerging base technology for spectral imaging and material differentiation with numerous potential applications in diagnostic imaging. We report development of a Si-strip PCXD system originally developed for mammography adapted to spectral CT of musculoskeletal extremities, including challenges associated with sparse sampling, spectral calibration,

and optimization for higher energy x-ray beams.

Methods: A bench-top CT system was developed incorporating a Si-strip PCXD, fixed anode x-ray source, and rotational and translational motions to execute complex acquisition trajectories. Trajectories involving rotation and translation combined with iterative reconstruction were investigated, including single and multiple axial scans and longitudinal helical scans. The system was calibrated to provide accurate spectral separation in dual-energy three-material decomposition of soft-tissue, bone, and iodine. Image quality and decomposition accuracy were assessed in experiments using a phantom with pairs of bone and iodine inserts (3, 5, 15 and 20 mm) and an anthropomorphic wrist.

Results: The designed trajectories improved the sampling distribution from 56% minimum sampling of voxels to 75%. Use of iterative reconstruction (viz., penalized likelihood with edge preserving regularization) in combination with such trajectories resulted in a very low level of artifacts in images of the wrist. For large bone or iodine inserts (>5 mm diameter), the accuracy of material decomposition was ~11% for (50 mg/mL) bone and ~8% for (5 mg/mL) iodine with strong regularization. For smaller inserts, errors of 20-40% were observed and motivate improved methods for spectral calibration and optimization of the edge-preserving regularizer.

Conclusion: Use of PCXDs for three-material decomposition in joint imaging proved feasible through a combination of rotation-translation acquisition trajectories and iterative reconstruction with optimized regularization.

9412-34, Session 7

Pulse detection logic for multibin photon counting detectors: beyond the simple comparator

Scott S. Hsieh, Norbert J. Pelc, Stanford Univ. (United States)

Energy-discriminating, photon counting (EDPC) detectors have been proposed for CT systems for their spectral imaging capabilities, improved dose efficiency and higher spatial resolution. However, these advantages disappear at high flux because of the damaging effects of pulse pileup. From an information theoretic standpoint, spectral information is lost. The information loss is particularly high when we assume that the EDPC detector extracts information using a bank of comparators, as current EDPC detectors use. We propose the use of alternative pulse detection logic which could preserve information in the presence of pileup. For example, the peak-only detector counts only a single event at the peak energy of multiple pulses which are piled up. We describe and evaluate five of these alternatives in simulation by numerically estimating the Cramer-Rao lower bound of the variance. At high flux, these alternative mechanisms can perform much better. In spectral imaging tasks, the variance reduction can be as high as an order of magnitude.

9412-35, Session 7

Evaluation of spectral CT data acquisition methods via non-stochastic variance maps

Adrian A. Sanchez, Emil Y. Sidky, The Univ. of Chicago Medical Ctr. (United States); Taly Gilat Schmidt, Marquette Univ. (United States); Xiaochuan Pan, The Univ. of Chicago Medical Ctr. (United States)

Recently, photon counting detectors capable of extracting spectral information have received much attention in CT, with promise of using spectral information to construct material basis images, correct beam-hardening artifacts, or provide improved imaging of K-edge contrast agents. In this work, we focus on the goal of constructing images of basis material maps, and investigate the feasibility of analytically computing pixel variance maps for these images, so that alternative data acquisition and reconstruction methods can be compared and evaluated with respect

to their noise properties. Our approach is based on linearization of the basis material decomposition and reconstruction operations, and we therefore demonstrate the method using the ubiquitous filtered back-projection algorithm, which is linear. We then performed preliminary investigation of the method by comparing basis material variance maps for two data acquisition methods that were previously found to have different noise properties: two-sided bin measurements acquired from separate, independent data realizations and two-sided bin measurements acquired from a single data realization.

9412-36, Session 7

Low rank approximation based noise reduction in spectral CT imaging using photon counting detector

Yinsheng Li, Univ. of Wisconsin-Madison (United States); Jiang Hsieh, GE Healthcare (United States); Guang-Hong Chen, Univ. of Wisconsin-Madison (United States)

Spectral imaging with photon counting detectors has recently attracted a lot of interest in X-ray and CT imaging by promising the elimination of electronic noise and thus enable ultra low radiation dose x-ray imaging. However, when radiation exposure levels are low, quantum noise may be prohibitively high hindering applications. Therefore, it is desirable to develop new methods to reduce quantum noise in acquired data using photon counting detectors. In this paper, we propose a new denoising algorithm to reduce quantum noise in data acquired using an ideal photon counting detector. The proposed method exploits the intrinsic low dimensionality of acquired spectral data to decompose the acquired data in a series of orthonormal spectral bases. The first few spectral bases contain object information while the rest of the bases contain primarily quantum noise. Therefore, a soft thresholding may be applied to truncate the dimension of the spectral basis and thus reduce noise in the acquired projection data. Numerical simulations were conducted to validate and evaluate the proposed noise reduction algorithm. The results demonstrated that the proposed method can effectively reduce quantum noise while maintaining both spatial and spectral fidelity.

9412-37, Session 7

Multivariate Gaussian model based Cramér–Rao lower bound evaluation of the in-depth PCXD

Yuan Yao, Norbert J. Pelc, Stanford Univ. (United States)

Purpose: In-Depth photon counting detectors (PCXD) use edge-on configuration and have multi-layer segmentations. Inter-layer cross-talk introduces correlation to the signal collected from each layer, which makes the independent Poisson model no longer valid for estimating the Cramér-Rao lower bound (CRLB) of the material decomposition. We proposed to use a multivariate Gaussian model as the substitute address the data correlation.

Methods: 120 kVp incident spectrum was simulated through 25cm of water and 1cm of calcium. 5-layer In-Depth and 1-layer Edge-On PCXDs with full energy resolution was simulated. We selected Si, GaAs and CdTe as the detector materials. The detectors were defined to have 1mm wide pixels and 70mm (Si), 10.5mm (GaAs) and 3mm (CdTe) thick. Geant4 was used for Monte Carlo simulation and energy response functions (ERF) capturing secondary events effect were obtained, together with the Gaussian parameter estimates. Using both models, we evaluated the CRLBs of the In-Depth and Edge-On detectors for each material and the systematic variance bounds were compared using correct model.

Results: For the uncorrelated data, the Gaussian and Poisson model based CRLBs are almost identical (±0.05%). As the data becomes more correlated, the Poisson CRLB starts to deviate from the Gaussian CRLB. Assessed by the corrected lower bounds, the In-Depth detector outperforms the Edge-

On detector and the improvement varies from 3% to 25% depending on the detector materials.

Conclusions: Multivariate Gaussian model is validated to be a good substitute to the Poisson model for PCXD CRLB estimation which can avoid the failure caused by correlated measurements.

9412-38, Session 7

Energy calibration of photon counting detectors using x-ray tube potential as a reference for material decomposition applications

Mini Das, Bigyan Kandel, Chan Soo Park, Zhihua Liang, Univ. of Houston (United States)

Photon counting spectral detectors (PCSD) with smaller pixels and efficient sensors are desirable in applications like material decomposition and phase contrast x-ray imaging where discrimination of small signals and fine structure may be desired. Charge sharing in PCSD increases with decreasing pixel sizes and increasing sensor thickness to extend that energy calibration or utility of spectral information can become a major hurdle. Utility of a combination of high Z sensors and small pixel sizes in PCSD is limited without efficient threshold calibration and charge sharing mitigation. Here we explore the utility of x-ray tube kVp as a reference to achieve efficient and fast calibration of PCSDs. This calibration method itself does not require rearranging the imaging setup and is not impacted by charge sharing. Our preliminary results indicate that this method can be useful even in scenarios where metal fluorescence and radioactive source based calibration techniques may be practically impossible. Our results are validated using x-ray fluorescence based calibration for a Silicon detector with moderate charge sharing. Calibration of a particularly challenging case of a Medipix2 detector (55 μm pixel size) with a 1 mm thick CdTe sensor is also demonstrated. The fidelity of the calibration using K-edge imaging methods and utility of these detectors in material decomposition and multi-energy imaging applications is being examined for both 55 and 110 μm pixel with CdTe sensor (Medipix2 and Medipix3).

9412-39, Session 7

Modelling the channel-wise count response of a photon-counting spectral CT detector to a broad x-ray spectrum

Xuejin Liu, Han Chen, Hans Bornefalk, Mats E. Danielsson, Staffan Karlsson, Mats Persson, Cheng Xu, Ben Huber, KTH Royal Institute of Technology (Sweden)

We develop a simulation model for a photon-counting spectral CT detector that allows precise predictions of the count response of energy bins in different detector elements. Parameters in this model include the incident x-ray spectrum, the detector absorption efficiency as well as the bin response function, which needs the values of energy bin thresholds for each detector element.

Technically, the threshold positions are set by voltage values in units of mV. This means that the determination of energy thresholds in units of keV for each detector element needs the energy calibration results, in our case, the values of gain and offset for detector elements. We develop an energy calibration method, which makes use of the broad x-ray spectrum provided by commercial x-ray tubes instead of the typical monoenergetic radiations at synchrotron sources. Gain and offset as the calibration parameters are obtained by a regression analysis that adjusts a simulated spectrum of deposited energies to a measured pulse-height spectrum. We verify the method for different detector channels with the aid of a table-top setup, where we find the uncertainty of the keV-value of a calibrated threshold lying between 0.1 and 0.2 keV. By plugging the calibrated keV-value of energy bin thresholds in the detector simulation model, the distribution of

counts in bins of each detector element to any incident spectrum can be predicted. We further investigate a possible reduction of the bias between measurement and model making use of measured absorptions with different material thicknesses.

9412-500, Session PL

4/5D imaging for guiding intracardiac and extracorporeal ablation of cardiac arrhythmias

Douglas L. Packer, Mayo Clinic (United States)

No Abstract Available

9412-40, Session 8

Quantitative imaging as a cancer biomarker *(Keynote Presentation)*

David A. Mankoff, Hospital of the Univ. of Pennsylvania (United States)

The ability to assay tumor biologic features and the impact of drugs on tumor biology is fundamental to drug development. Advances in our ability to measure genomics, gene expression, protein expression, and cellular biology have led to a host of new targets for anticancer drug therapy. In translating new drugs into clinical trials and clinical practice, these same assays serve to identify patients most likely to benefit from specific anticancer treatments. As cancer therapy becomes more individualized and targeted, there is an increasing need to characterize tumors and identify therapeutic targets to select therapy most likely to be successful in treating the individual patient's cancer. Thus far assays to identify cancer therapeutic targets or anticancer drug pharmacodynamics have been based upon in vitro assay of tissue or blood samples. Advances in molecular imaging, particularly PET have led to the ability to perform quantitative non-invasive molecular assays. Imaging has traditionally relied on structural and anatomic features to detect cancer and determine its extent. More recently, imaging has expanded to include the ability to image regional biochemistry and molecular biology, often termed molecular imaging. Molecular imaging can be considered an in vivo assay technique, capable of measuring regional tumor biology without perturbing it. This makes molecular imaging a unique tool for cancer drug development, complementary to traditional assay methods, and a potentially powerful method for guiding targeted therapy in clinical trials and clinical practice. The ability to quantify, in absolute measures, regional in vivo biologic parameters strongly supports the use of molecular imaging as a tool to guide therapy.

9412-41, Session 8

Respiratory motion compensation for simultaneous PET/MR based on a 3D-2D registration of strongly undersampled radial MR data - a simulation study

Christopher M. Rank, Thorsten Heusser, Barbara Flach, Marcus Brehm, Marc Kachelrieß, Deutsches Krebsforschungszentrum (Germany)

We propose a new method for PET/MR respiratory Motion Compensation (MoCo), which is based on a 3D-2D registration of strongly undersampled MR data and a) runs in parallel with the PET acquisition, b) can be interlaced with clinical MR sequences, and c) requires less than one minute of the total MR acquisition time per bed position. In our simulation study, we used a 2D radial stack-of-stars sampling scheme with 160 radial spokes per slice and an acquisition time of 48 s to continuously monitor patient motion

during PET/MR acquisitions. Gated 4D MR images were reconstructed using a 4D iterative reconstruction algorithm. Based on these images, motion vector fields were estimated using our newly-developed 3D-2D registration algorithm. A 4D PET volume of a patient with two hot lung lesions was simulated and MoCo 4D PET images were reconstructed based on the motion vector fields derived from MR. For evaluation, mean SUV values of both artificial lesions were determined for all ten motion phases for a 3D, a gated 4D, a MoCo 4D and a reference (with ten-fold measurement time) gated 4D reconstruction. Compared to the reference, 3D reconstructions yielded an underestimation of mean SUV values due to motion blurring. In contrast, gated 4D reconstructions showed the highest variation of mean SUV due to low statistics. MoCo 4D reconstructions were only slightly affected by these two sources of uncertainty resulting in a significant visual and quantitative improvement. Whereas temporal resolution was comparable to the gated 4D images, signal-to-noise ratio and contrast-to-noise ratio were close to the 3D reconstructions.

9412-42, Session 8

Theoretical and experimental comparison of image signal and noise for dual-energy subtraction angiography and conventional x-ray angiography

Christiane S. Burton, Ian A. Cunningham, Robarts Research Institute (Canada); John R. Mayo, Vancouver Coastal Health Research Institute (Canada)

Cardiovascular disease (CVD) is the leading cause of mortality worldwide. Digital subtraction angiography (DSA), widely used for vascular imaging, removes anatomic structures by subtracting a pre-injection (mask) image and post-injection (contrast) image. However, any motion that occurs during the time gap of several seconds between mask and contrast images results in improper subtraction that may obscure important details of iodinated vessels making DSA largely unsuccessful for cardiovascular imaging. We are investigating energy subtraction angiography (ESA) that, instead of a mask image, uses two contrast images acquired at low and high energies in rapid succession (~10 ms) to eliminate motion artifacts. Dual-energy angiography has been suggested previously, however it was found image quality was generally inferior to DSA. We have shown both theoretically and experimentally that ESA can provide angiographic images with comparable iodine SNR to DSA for low iodine concentrations for similar patient exposures. We have acquired DSA and ESA images of a vascular phantom and measured the iodine signal-to-noise ratio (SNR) per root exposure with experiment showing excellent agreement with theory. We conclude that with current detector equipment it is possible to obtain angiographic images of iodinated structures using ESA with signal and noise that is comparable to DSA with similar patient entrance exposure.

9412-43, Session 9

A quantitative metrology for performance characterization of breast tomosynthesis systems based on an anthropomorphic phantom

Lynda C. Ikejimba, Carl E. Ravin Advanced Imaging Labs., Duke Univ. (United States) and Duke Univ. Medical Ctr. (United States) and Medical Physics Graduate Program, Duke Univ. (United States); Yicheng Chen, Tsinghua Univ. (China) and Carl E. Ravin Advanced Imaging Labs., Duke Univ. (United States); Nadia Oberhofer, Azienda Sanitaria dell'AltoAdige (Italy); Nooshin Kiarashi, Carl E. Ravin Advanced Imaging Labs., Duke Univ. (United States) and Duke Univ. Medical Ctr. (United States); Joseph Y. Lo,

Ehsan Samei, Carl E. Ravin Advanced Imaging Labs., Duke Univ. (United States) and Duke Univ. Medical Ctr. (United States) and Medical Physics Graduate Program, Duke Univ. (United States)

Common methods for assessing image quality of breast tomosynthesis devices currently utilize simplified or otherwise unrealistic phantoms, which use inserts in a uniform background and gauge performance based on a subjective evaluation of insert visibility. This study proposes a different methodology to assess system performance using a three-dimensional clinically-informed anthropomorphic breast phantom. In this method, the imaging performance of the system, as a whole, is assessed by imaging the phantom and computationally characterizing the resultant images in terms of three new metrics. Those include a contrast index (reflective of local difference between adipose and glandular material) and a heterogeneity index (reflective of background non-uniformity within uniform adipose tissue. The method was evaluated in the context of characterizing five tomosynthesis systems from three vendors at two dose levels (according to expected clinical protocol and a fixed 1.5 mGy AGD) in comparison with standard methods using the ACR mammography phantom. The contrast index results from the phantom exhibited notable differences between systems (0.01-0.05), with trends consistent with the ACR phantom results. The heterogeneity index similarly exhibited system-dependencies correlated with visual appearance of non-uniformities from out-of-plane artifacts. The findings illustrate that the anthropomorphic phantom can be used as a quality control tool with results that are targeted to be more reflective of clinical performance of breast tomosynthesis systems of multiple manufacturers.

9412-44, Session 9

Volumetric limiting spatial resolution analysis of four dimensional digital subtraction angiography (4D-DSA)

Brian J. Davis, Erick L. Oberstar, Univ. of Wisconsin-Madison (United States); Kevin L. Royalty, Siemens Medical Solutions USA, Inc. (United States) and Univ. of Wisconsin-Madison (United States); Sebastian Schafer, Siemens Medical Solutions USA, Inc. (United States); Charles M. Strother, Charles A. Mistretta, Univ. of Wisconsin-Madison (United States)

Static C-Arm CT 3D FDK baseline reconstructions (BR) are unable to provide temporal information to radiologists. 4D-DSA provides a time series of 3D volumes implementing a constrained image, thresholded BR, reconstruction utilizing temporal dynamics in the 2D projections. Volumetric limiting spatial resolution (VLSR) of 4D-DSA is quantified and compared to a BR reconstruction using the same BR parameters. Investigated were the effects of varying over significant ranges the 4D-DSA parameters of 2D blurring kernel size applied to the projection and threshold applied to the 3D BR when generating the constraining image of a scanned phantom (SPH) and an electronic phantom (EPH). The SPH consisted of a 76 micron tungsten wire encased in a 47 mm O.D. plastic radially concentric thin walled support structure. An 8-second/248-frame/198° scan protocol acquired the raw projection data. VLSR was determined from averaged MTF curves generated from each 2D transverse slice of every (248) 4D temporal frame (3D). 4D results for SPH and EPH were compared to the BR. Analysis of the BR resulted in a VLSR of 2.28 and 1.69 lp/mm for the EPH and SPH respectively. Kernel (2D) sizes of either 10x10 or 20x20 pixels with a threshold of 10% of the BR as a constraining image provided 4D-DSA VLSR nearest to the BR. 4D-DSA algorithms yielded 2.21 and 1.67 lp/mm with a percent error of 3.1% and 1.2% for the EPH and SPH respectively as compared to the BR. This research indicates 4D-DSA is capable of retaining the resolution of the BR.

9412-45, Session 9

New family of generalized metrics for comparative imaging system evaluation

Megan K. Russ, Vivek Singh, Brendan M. Loughran, Daniel R. Bednarek, Stephen Rudin, Univ. at Buffalo (United States)

A family of imaging task-specific metrics designated Relative Object Detectability (ROD) metrics was developed to enable objective, quantitative comparisons of different x-ray systems. Previously, ROD was defined as the integral over spatial frequencies of the Fourier Transform of the object function, weighted by the detector DQE for one detector, divided by the comparable integral for another detector. When effects of scatter and focal spot unsharpness are included, the generalized metric, GDQE, is substituted for the DQE, resulting in the G-ROD metric. The G-ROD was calculated for two different detectors with two focal spot sizes using various-sized simulated objects to quantify the improved performance of new high-resolution CMOS detector systems. When a measured image is used as the object, a Generalized Measured Relative Object Detectability (GM-ROD) value can be generated. A neuro-vascular stent (Wingspan) was imaged with the high-resolution Micro-Angiographic Fluoroscope (MAF) and a standard flat panel detector (FPD) for comparison using the GM-ROD calculation. As the lower integration bound increased from 0 toward the detector Nyquist frequency, increasingly superior performance of the MAF in imaging small objects was evidenced. Another new metric, the R-ROD, enables comparing detectors to a reference detector of given imaging ability. R-RODs for the MAF, a new CMOS detector and an FPD will be presented. The ROD family of metrics can provide quantitative comparisons for different systems where the detector, focal spot, scatter, object, techniques or dose are varied and can be used to optimize system selection for given imaging tasks.

9412-46, Session 9

Approximate path seeking for statistical iterative reconstruction

Meng Wu, Stanford Univ. (United States); Qiao Yang, Andreas K. Maier, Friedrich-Alexander-Univ. Erlangen-Nürnberg (Germany); Rebecca Fahrig, Stanford Univ. (United States)

Statistical iterative reconstruction (IR) techniques have demonstrated many advantages in X-ray CT reconstruction. The statistical iterative reconstruction approach is often modeled as an optimization problem including a data fitting function and a penalty function. The tuning parameter values that regulates the strength of the penalty function are critical for achieving good reconstruction results. However, appropriate turning parameter values that are suitable for the scan protocols and imaging tasks are often difficult to choose. In this work, we propose a path seeking algorithm that is capable of generating a series of IR images with different strengths of the penalty function. The path seeking algorithm uses the ratio of the gradients of the data fitting function and the penalty function to select pixels for small fixed size updates. We describe the path seeking algorithm for penalized weighted least squares (PWLS) with Huber penalty function in both the directions of increasing and decreasing tuning parameter value. Simulations using the XCAT phantom show the proposed method produces path images that are very similar to the IR images that are computed via direct optimization. The root-mean-squared-error of one path image generated by the proposed method related to full iterative reconstruction is about 6 HU for the entire image, and 10 HU for a small region. Different path seeking directions, increment sizes and updating percentages of the path seeking algorithm are compared in simulations. The proposed method may reduce the dependence on selection of good tuning parameter values by instead generating multiple IR images, without significantly increasing the computational load.

SPIE. MEDICAL IMAGING

9412-47, Session 9

Enhancing 4D PC-MRI in an aortic phantom considering numerical simulations

Jonas Kratzke, Nicolai J. Schoch, Ruprecht-Karls-Univ. Heidelberg (Germany); Christian Weis, UniversitätsKlinikum Heidelberg (Germany); Matthias Müller-Eschner, UniversitätsKlinikum Heidelberg (Germany) and Deutsches Krebsforschungszentrum (Germany); Stefanie Speidel, Karlsruher Institut für Technologie (Germany); Mina Farag, Carsten J. Beller, UniversitätsKlinikum Heidelberg (Germany); Vincent Heuveline, Ruprecht-Karls-Univ. Heidelberg (Germany)

We propose a framework that allows to enhance 4D phase contrast (PC)-MRI imaging by means of numerical simulations based on the Finite Element Method (FEM). The developed approach is applied to a simplified aortic phantom. The considered numerical model is calibrated by means of the 4D PC-MRI data with respect to the geometry and the boundary conditions.

Based on the physical methods of biomechanics and computational fluid dynamics, the derived simulation is able to depict flow behavior inside the aorta. It also shows alarming threshold values such as wall sheer stress along the aortic wall.

The proposed model is evaluated by comparing experimental and numerical data in the framework of an aortic phantom.

The obtained framework should therefore help identifying factors that induce aortic pathologies such as aortic dilatation or aortic dissection.

9412-48, Session 9

Experimental implementation of coded aperture coherent scatter spectral imaging of cancerous and healthy breast tissue samples

Manu N. Lakshmanan, Duke Univ. Medical Ctr. (United States); Joel A. Greenberg, Duke Univ. (United States); Ehsan Samei, Anuj J. Kapadia, Duke Univ. Medical Ctr. (United States)

Cancerous, adipose and fibroglandular tissues in the breast each give a unique coherent X-ray scatter signal. Therefore, coherent scatter imaging can be used to identify the type of breast tissue in a given voxel of a sample. In this work, we present an experimental coherent scatter imaging system for imaging of cancerous tumors. The system uses specialized coded apertures to provide axial-resolution without the need for tomography. We describe the working of the coded aperture coherent scatter imaging system and demonstrate its ability to image the distribution of cancerous tissue in a surgically resected breast cancer specimen.

9412-49, Session 10

Monte Carlo evaluation of the relationship between absorbed dose and contrast-to-noise ratio in coherent scatter breast CT

Bahaa Ghammraoui, Andreu Badal, Lucretiu M. Popescu, U.S. Food and Drug Administration (United States)

Purpose: The objective of this work was to evaluate the advantages and shortcomings associated with Coherent Scatter Computed Tomography (CSCT) systems for breast imaging and study possible alternative configurations. The relationship between dose in a breast phantom and a simple surrogate of image quality in pencil-beam and fan-beam CSCT geometries was evaluated via Monte Carlo simulation, and an improved pencil-beam setup was proposed for faster CSCT data acquisition.

Methods: CSCT projection datasets have been simulated using a new version of the MC-GPU code that includes an improved model of x-ray coherent scattering using experimentally measured molecular interference functions. The breast phantom was composed of an 8 cm diameter cylinder of 50/50 glandular/adipose material and nine rods with different diameters of materials intended to mimic cancerous, adipose and glandular tissues. The system performance has been assessed in terms of the contrast-to-noise ratio (CNR) in multiple regions of interest within the reconstructed images, for a range of exposure levels. The enhanced pencil-beam setup consisted of multiplexed pencil beams and specific postprocesxsing of the projection data to calculate the scatter intensity coming from each beam separately.

Results: At reconstruction spatial resolution of 1x1mm^2 and from 1 to 10 mGy of received breast dose, fan-beam geometry showed higher statistical noise and lower CNR than pencil-beam geometry. Conventional CT acquisition (reconstructed from projections at 0° angle) had the highest CNR per dose. However, the CSCT showed a relevant contrast between cancer and glandular tissue, which had the same intensity in conventional CT. Preliminary evaluation of the multiplexed pencil-beam geometry showed that the scattering profiles simulated with the new approach are similar to those of the single pencil-beam geometry.

Conclusion: It has been shown that the GPU-accelerated MC-GPU code is a practical tool to simulate complete CSCT scans with different acquisition geometries and exposure levels. The simulation showed better performance in terms of the received dose and CNR with pencil-beam geometry in comparison to the fan-beam geometry. Finally, we demonstrated that the proposed multiplexed-beam geometry might be useful for faster acquisition of CSCT while providing comparable CNR as the pencil-beam geometry.

9412-50, Session 10

Monte Carlo simulation of breast tomosynthesis: visibility of microcalcifications at different acquisition schemes

Hannie Petersson, Magnus Dustler, Pontus A. Timberg, Anders Tingberg, Lund Univ. (Sweden)

Microcalcifications are one feature of interest in mammography and breast tomosynthesis (BT). To achieve optimal detection of microcalcifications in BT imaging, the acquisition geometry has to be optimized. Through Monte Carlo simulations many different acquisition parameters can be evaluated without development of physical prototypes or human radiation exposure. The purpose of this work was to investigate influences of acquisitions with different angular ranges, projection and dose distributions on the visibility of microcalcifications in reconstructed BT volumes.

Microcalcifications were inserted randomly in a high resolution software phantom and the Monte Carlo code system PENELOPE was used to model a Siemens MAMMOMAT Inspiration BT system. Acquisitions with various combinations of angular range, projection distribution and dose distribution were generated. Analytical ray tracing was used to produce scatter and noise free images. Scatter contribution was simulated with Monte Carlo and system noise was modeled based on measured values from flatfield image acquisitions.

To compare the visibility and depth resolution of the microcalcifications, signal difference to noise ratio (SDNR) and artifact spread function width (ASFW) were calculated in the reconstructed volumes. Two-way ANOVA (analysis of variance) showed several significant (95 % confidence level) differences between the different acquisition schemes, whereof the depth resolution was highest for the standard acquisition scheme (with 25 projections evenly distributed over a 50° angular range) while the SDNR was suboptimal. The result suggests that other schemes than the standard should be considered for optimal microcalcification detection.

9412-51, Session 10

Asymmetric scatter kernels for software-based scatter correction of gridless mammography

Adam S. Wang, Varian Medical Systems, Inc (United States); Edward G. Shapiro, Sungwon Yoon, Cesar H. Proano, Rick Colbeth, Varian Medical Systems, Inc. (United States); Erkki Lehto, Planmed Oy (Finland); Josh M. Star-Lack, Varian Medical Systems, Inc. (United States)

Scattered radiation remains one of the primary challenges for digital mammography, resulting in decreased image contrast and visualization of key features. While anti-scatter grids are commonly used to reduce scattered radiation in digital mammography, they are an incomplete solution that adds radiation dose, cost, and complexity. Instead, a software-based scatter correction method utilizing asymmetric scatter kernels is developed and evaluated in this work, which improves upon conventional symmetric kernels by adapting to local variations in object thickness and attenuation that result from the heterogeneous nature of breast tissue. This fast adaptive scatter kernel superposition (fASKS) method was applied to mammography by generating scatter kernels specific to the object size, x-ray energy, and system geometry of the projection data. The method was first validated with Monte Carlo simulation of a statistically-defined digital breast phantom, which was followed by initial validation on phantom studies conducted on a clinical mammography system. Results from the Monte Carlo simulation demonstrate excellent agreement between the estimated and true primary signal, resulting in accurate scatter correction and image contrast recovery of 87%. Additionally, the asymmetric kernel provided more accurate scatter correction than the conventional symmetric kernel, especially at the edge of the breast. Results from the phantom studies on a clinical system further validate the ability of the asymmetric kernel correction method to accurately subtract the scatter signal and improve image quality. In conclusion, software-based scatter correction for mammography is a promising alternative to hardware-based approaches such as anti-scatter grids.

9412-52, Session 10

Anatomical noise power in breast imaging with differential phase contrast and dark field imaging

John W. Garrett, Yongshuai Ge, Ke Li, Guang-Hong Chen, Univ. of Wisconsin-Madison (United States)

In x-ray breast imaging, the anatomical noise background of the breast has a significant impact on the detection of lesions and other features of interest. This anatomical noise is typically characterized by a parameter, β, which describes a power law dependence of anatomical noise on spatial frequency (the shape of the anatomical noise power spectrum). Large values of β have been shown to reduce human detection performance, and in conventional mammography typical values of β are around 3.2. Recently, x-ray differential phase contrast (DPC) and the associated dark field imaging methods have received considerable attention as possible supplements to absorption imaging for breast cancer diagnosis. However, the impact of these additional contrast mechanisms on lesion detection is not yet well understood. In order to better understand the utility of these new methods, we measured the β indices for absorption, DPC, and dark field images in 15 cadaver breast specimens using a benchtop DPC imaging system. We found that the measured β value for absorption was consistent with the literature for mammographic acquisitions ($\beta=3.61\pm0.49$), but that both DPC and dark field images had much lower values of β ($\beta=2.54\pm0.75$ for DPC and $\beta=1.44\pm0.49$ for dark field). In addition, visual inspection showed greatly reduced anatomical background in both DPC and dark field images. These promising results suggest that DPC and dark field imaging may help provide improved lesion detection in breast imaging, particularly for those patients with dense breasts, in whom anatomical noise is a major limiting factor in identifying malignancies.

9412-53, Session 10

Three dimensional dose distribution comparison of simple and complex acquisition trajectories in dedicated breast CT using radiochromic film

Jainil P. Shah, Steve D. Mann, Duke Univ. (United States); Randolph L. McKinley, ZumaTek, Inc. (United States); Martin P. Tornai, Duke Univ. (United States)

A novel breast CT system capable of arbitrary 3D trajectories has been developed to address cone beam sampling insufficiency as well as to image further into the patient's chest wall. The purpose of this study was to characterize any trajectory-related differences in 3D x-ray dose distribution in a pendant target when imaged with different orbits. Three cylindrical phantoms of different diameters (10, 12.5 and 15cm) and an anthropomorphic breast phantom, initially filled with water and then with a 75% methanol-25% water mixture, were used to simulate the pendant breast geometry and scanned with two acquisition trajectories: azimuthal orbit (AZOR) with no tilt, and a complex sinusoidal (saddle) orbit with ±15° tilts. Fully-3D CT scans were performed using a tungsten anode source, once with tungsten and once with cerium filtration. Ionization chamber calibrated radiochromic film was used to determine average dose delivered as well as to visualize the 2D dose distribution in the center of the volume. Results indicated that the mean dose measured at the central slice across different diameters ranged from 3.93 to 5.28 mGy with the lowest average dose measured on the largest cylinder. More importantly, in all cases, dose delivered by the saddle scan was consistently 1-3% lower than the AZOR scans. These results corroborate previous cylinder Monte Carlo studies which showed a 1% reduction in saddle dose. The average dose measured in the breast phantom filled with 75% methanol-25% water was slightly higher for saddle than AZOR - 3.82 and 3.87mGy respectively.

9412-54, Session 11

Fluid-filled dynamic bowtie filter: a feasibility study

Picha Shunhavanich, Scott S. Hsieh, Norbert J. Pelc, Stanford Univ. (United States)

By varying its thickness to compensate for the variable path length of the patient as a function of fan angle, a pre-patient bowtie filter modulates flux distribution to reduce patient dose, scatter, and detector dynamic range, and to improve image quality. A dynamic bowtie filter is superior to its traditional, static counterpart in its ability to adjust its thickness along different fan and view angles to suit a specific patient. Among the proposed dynamic bowtie designs, the piecewise-linear and the digital beam attenuator offer more flexibility than conventional filters, but rely on analog positioning of a limited number of wedges. In this work, we introduce a new approach with digital control, called the fluid-filled dynamic bowtie filter. It is a two-dimensional array of small binary elements (channels filled or unfilled with attenuating liquid) in which the cumulative thickness along the x-ray path contributes to the bowtie's total attenuation. Using the simulation data from pelvis scan, the performance is compared with the piecewise-linear attenuator. The fluid-filled design better matches the target attenuation profile, with a 3.1x improvement in RMSE and a 4.3x reduction in dynamic range. The variance of the reconstruction (or noise map) is also more homogeneous. From the initial simulation results, the proposed design has more control over the flux distribution as a function of both fan and view angles.

9412-55, Session 11

Imaging task-based optimal kV and mA selection for CT radiation dose reduction: from filtered backprojection (FBP) to statistical model based iterative reconstruction (MBIR)

Ke Li, Daniel Gomez-Cardona, Meghan G. Lubner, Perry J. Pickhardt, Guang-Hong Chen, Univ. of Wisconsin-Madison (United States)

Optimal selections of tube potential (kV) and tube current (mA) are essential in maximizing the diagnostic potential of a given CT technology while minimizing radiation dose. The use of a lower tube potential may improve image contrast, but may also require a significantly higher tube current to compensate for the rapid decrease of tube output at lower tube potentials. The optimal kV and mA should be determined using a task-based approach in which image quality and diagnostic performance at different kV-mA combinations are assessed for each patient size and imaging task. For conventional quasi-linear CT systems employing linear filtered backprojection (FBP) image reconstruction algorithms, the optimization of kV-mA combinations are relatively straightforward, as neither spatial resolution nor noise texture has significant dependence on kV and mA settings. In these cases, zero-frequency analysis such as contrast-to-noise ratio (CNR) or normalized CNR by dose (CNRD) can be utilized for kV and mA optimization. However, for the recently introduced statistical model-based iterative reconstruction (MBIR) methods, new challenges to optimal kV and mA selection have been introduced, as both spatial resolution and noise texture become closely correlated with scan settings such as mA. In this work, the classical task-based approach along with modern signal detection theory and the corresponding frequency-dependent analysis has been proposed to perform the kV-mA optimization by exhaustively searching through the technically accessible kV-mA parameter space. Iso-distributions of the detectability index (d') for detecting a renal lesion in an anthropomorphic abdomen phantom was generated to guide the selection of tube potential and current. Our results not only demonstrated that MBIR can help reduce radiation dose, but also suggested that an optimal selection of kV and mA enables this method to realize its maximum dose reduction potential.

9412-56, Session 11

First results from a prototype dynamic attenuator system

Scott S. Hsieh, Mark V. Peng, Christopher A. May, Picha Shunhavanich, Norbert J. Pelc, Stanford Univ. (United States)

The dynamic, piecewise-linear attenuator has been proposed as a concept which can shape the radiation flux incident on the patient. By reducing the signal to photon-rich measurements and increasing the signal to photon-starved measurements, the piecewise-linear attenuator has been shown to improve dynamic range, scatter, and variance and dose metrics in simulation. The piecewise-linear nature of the proposed attenuator has been hypothesized to mitigate artifacts at transitions by eliminating jump discontinuities in attenuator thickness at these points. We report the results of a prototype implementation of this concept. The prototype was constructed using rapid prototyping technologies and was affixed to a tabletop x-ray system. Images of several sections of an anthropormophic pediatric phantom were produced and compared to those of a system with uniform illumination. The thickness of the illuminated slab was limited by beam collimation and an analytic water beam hardening correction was used for both systems. Initial results are encouraging and show improved image quality, reduced dose and low artifact levels.

9412-57, Session 11

Ultra low radiation dose digital subtraction angiography (DSA) imaging using low rank constraint

Kai Niu, Yinsheng Li, Univ. of Wisconsin-Madison (United States); Sebastian Schafer, Kevin L. Royalty, Siemens Medical Solutions USA, Inc. (United States); Yijing Wu, Charles M. Strother, Guang-Hong Chen, Univ. of Wisconsin-Madison (United States)

In this work we developed a novel denoising algorithm for DSA image series. This algorithm takes advantage of the low rank nature of the DSA image sequences to enable a dramatic reduction in radiation and/or contrast doses in DSA imaging. Both spatial and temporal regularizers were introduced in the optimization algorithm to further reduce noise. To validate the method, in vivo animal studies were conducted with a Siemens Artis Zee biplane system using different radiation dose levels and contrast concentrations. Both conventionally processed DSA images and the DSA images generated using the novel denoising method were compared using absolute noise standard deviation and the contrast to noise ratio (CNR). Two ROIs were used to measure the noise level and CNR for each DSA dataset. One ROI was placed over the maxillary artery, and the other was placed in a uniform background region near the artery, but containing no vasculature. All measurements were done at the same time point for each DSA dataset. With the application of the novel denoising algorithm for DSA, image quality can be maintained with a radiation dose reduction by a factor of 20 and/or a factor of 2 reduction in contrast dose. Image processing is completed on a GPU within a second for a 10s DSA data acquisition.

9412-58, Session 12

Evaluation of a video-based head motion tracking system for dedicated brain PET

Sergey Anishchenko, Univ. of Maryland, Baltimore (United States) and A.B. Kogan Research Institute for Neurocybernetics, Southern Federal Univ. (Russian Federation); David M. Beylin, Pavel S. Stepanov, Brain Biosciences Inc. (United States); Alex Stepanov, Brain Biosciences, Inc. (United States); Irving N. Weinberg, Stephen Schaeffer, Brain Biosciences Inc. (United States); Valery Zavarzin, Brain Biosciences (United States); Dmitry G. Shaposhnikov, A.B. Kogan Research Institute for Neurocybernetics, Southern Federal Univ. (Russian Federation); Mark F. Smith, Univ. of Maryland, Baltimore (United States)

Unintentional head motion during Positron Emission Tomography (PET) data acquisition can degrade PET image quality and lead to artifacts. Poor patient compliance, head tremor, and coughing are sources of movement. Head motion due to patient non-compliance becomes particularly common with the rise of amyloid brain PET in dementia patients. To preserve PET image resolution and quantitative accuracy, head motion should be tracked and corrected in the image reconstruction algorithm. While fiducial markers can be used, a contactless video-based approach is preferable.

A video-based head motion tracking system for a dedicated portable high-resolution brain PET scanner was developed. Four wide-angle (120o, 640x480, 30 fps) cameras organized in two stereo pairs are used for capturing video. The stereo pairs are calibrated with respect to the PET device. Facial points are automatically tracked on video captured during the PET data acquisition. The facial points are used to determine 6 degree of freedom head pose during the study.

To evaluate the system performance, video data were acquired with a head phantom. A magnetic tracking device (MTD) attached to the phantom was

used to measure ground truth. The facial points were tracked with both the MTD and the video-based motion tracking system. Translation and rotation of the phantom lead to facial point displacements of up to 50mm. The average full width at half maximum (FWHM) video-tracking error was 1.7mm (range 0.9mm-2.7mm) relative to the MTD. The video-tracking algorithm performance is being evaluated in a study with twenty-five human subjects.

9412-59, Session 12

Computation of synthetic mammograms with an edge-weighting algorithm

Klaus Erhard, Hanno Homann, Frank Bergner, Philips Research (Germany)

The promising increase in cancer detection rates makes digital breast tomosynthesis (DBT) an interesting alternative to full-field digital mammography (FFDM) for breast cancer screening. However, this benefit comes at the cost of an increased average glandular dose in a combined DBT plus FFDM acquisition protocol. Synthetic mammograms, which are computed from the reconstructed tomosynthesis volume data, have demonstrated to be an alternative to a regular FFDM exposure in a DBT plus synthetic 2D reading mode. Recently published methods are based on integrating CAD techniques for computing a weighting function in the forward projection step of the synthetic mammogram generation. In this work, a novel and computationally efficient method is presented based on an edge-retaining algorithm, which directly computes the weighting function by an edge-detection filter.

The diagnostic assessment of a structure is often determined by the outline contour rather than by its brightness. Therefore, an edge-intensity measure, defined locally for every voxel position, is implemented for computing a 3D weighting function from the reconstructed tomosynthesis volume data. The stack of slice reconstructions is generated with an iterative reconstruction algorithm. The Sobel operator is used as a compromise between spatial compactness and robustness against noise for computing the edge-intensity measure in the generation of synthetic mammograms. The proposed algorithm has been evaluated on clinical data acquired on a Philips MicroDose tomosynthesis prototype system. Structures from the tomosynthesis slices are generally preserved and sharply represented in the synthetic view and the visibility of micro-calcifications was not compromised with the proposed method.

9412-60, Session 12

Lesion insertion in projection domain for CT image quality assessment

Baiyu Chen, Zhicong Yu, Shuai Leng, Lifeng Yu, Cynthia H. McCollough, Mayo Clinic (United States)

To perform task-based image quality assessment in CT, it is desirable to have a large number of realistic patient images with known diagnostic truth. One effective way to achieve this objective is to create hybrid images that combine patient images with simulated lesions. Because conventional hybrid images generated in the image-domain fails to reflect the impact of scan and reconstruction parameters on lesion appearance, this study explored a projection-domain approach. Liver lesion models were forward projected according to the geometry of a commercial CT scanner to acquire lesion projections. The lesion projections were then inserted into patient projections and reconstructed to acquire hybrid images. To validate the accuracy of the forward projection geometry, simulated images reconstructed from the forward projections of a digital ACR phantom were compared to physically acquired ACR phantom images. To validate the hybrid images, a lesion model was inserted into patient images and visually assessed. Results showed that the simulated phantom images and the physically acquired phantom images had great overall similarity. The mean HU of the simulated image was around 3 HU higher than that of the physically acquired phantom image, which can be calibrated and was also expected because a monoenergetic beam instead of a polychromatic beam

was used to simulate forward projections. The hybrid image had a realistic appearance. The inserted lesion merged naturally into the liver background and demonstrated kernel-dependent appearance. Compared to conventional image-domain approach, our method enables more realistic hybrid images for image quality assessment.

9412-61, Session 12

Examining wide-arc digital breast tomosynthesis: optimization using a visual-search model observer

Mini Das, Zhihua Liang, Howard C. Gifford, Univ. of Houston (United States)

Mathematical model observers are expected to assist in preclinical optimization of image acquisition and reconstruction parameters. A clinically realistic and robust model observer platform could help in multiparameter optimizations without requiring frequent human-observer validations. We are developing search-capable visual-search (VS) model observers with this potential. In this abstract, we present initial results on optimization of DBT scan angle and the number of projection views for low-contrast mass detection. Comparison with human-observer results shows very good agreement. These results point towards the benefits of using relatively wider arcs and low projection angles per arc degree for improved mass detection. These results are particularly interesting considering that the sole FDA-approved DBT system (Hologic Selenia Dimensions) uses a 15-degree acquisition arc and one projection per arc degree.

9412-62, Session 12

Performance comparison of breast imaging modalities using a 4AFC human observer study

Premkumar Elangovan, Univ. of Surrey (United Kingdom); Alaleh Rashidnasab, Univ. of Surrey (United Kingdom) and Univ. Hospitals Leuven (Belgium); Alistair Mackenzie, David R. Dance, Kenneth C. Young, The Royal Surrey County Hospital NHS Trust (United Kingdom) and Univ. of Surrey (United Kingdom); Hilde Bosans, Univ. Hospitals Leuven (Belgium); William P. Segars, Duke Univ. (United States); Kevin Wells, Univ. of Surrey (United Kingdom)

This work aims to compare the visibility of spheres and simulated masses in 2D-mammography and tomosynthesis systems using human observer studies. Performing comparison studies between imaging systems poses a number of practical challenges within a clinical environment. We therefore adopted an approach which included realistic breast phantoms, a validated lesion simulation model and a set of validated image modelling tools as a viable alternative. A series of 4-alternative forced choice (4AFC) human observer experiments were conducted where physicists were presented with signal detection tasks using masses and spheres as targets excluding the radiologist image search process. Four physicists participated in a preliminary study containing images with 3mm and 7mm targets at a range of contrast levels comprising 60 trials per experimental condition. The results from the pilot study showed that tomosynthesis has a lower threshold contrast than 2D-mammography for masses and spheres, and moreover, detection studies using spheres may produce overly-optimistic threshold contrast values. These initial findings have been used to provide guidelines for estimating the testing power and sample size for a more detailed study to be presented for the first time in the extended version of this paper

9412-63, Session 13

X-ray attenuation of adipose breast tissue: in-vitro and in-vivo measurements using spectral imaging

Erik Fredenberg, Philips Healthcare (Sweden); Klaus Erhard, Philips Research (Germany); Karl Berggren, Philips Healthcare (Sweden); David R. Dance, The Royal Surrey County Hospital NHS Trust (United Kingdom) and Univ. of Surrey (United Kingdom); Kenneth C. Young, The Royal Surrey County Hospital NHS Trust (United Kingdom) and Univ. of Surrey (United Kingdom); Björn Cederström, Henrik Johansson, Mats Lundqvist, Elin Moa, Philips Healthcare (Sweden); Hanno Homann, Philips Research (Germany); Paula Willsher, Fleur Kilburn-Toppin, Cambridge Breast Unit (United Kingdom) and NIHR Cambridge Biomedical Research Ctr. (United Kingdom); Matthew G. Wallis, Cambridge Breast Unit (United Kingdom) and NIHR Cambridge Biomedical Research Ctr. (United Kingdom)

The development of new x-ray imaging techniques often requires prior knowledge of tissue attenuation, but the sources of such information are sparse. We have measured the attenuation of adipose breast tissue using spectral imaging, in vitro and in vivo. For the in-vitro measurement, fixed samples of adipose breast tissue were imaged on a spectral mammography system, and the energy-dependent x-ray attenuation was measured in terms of equivalent thicknesses of aluminum and poly-methyl methacrylate (PMMA). For the in-vivo measurement, a similar procedure was applied on a number of spectral screening mammograms. The results of the two measurements agreed well and were consistent with published attenuation data and with measurements on tissue-equivalent material.

9412-64, Session 13

A method for the production of customized epoxy resin x-ray filters for use within the bore of gantry-based micro-CT scanners

Justin J. Tse, Joy Dunmore-Buyze, Maria Drangova, David W. Holdsworth, The Univ. of Western Ontario (Canada)

The ability to tailor the output x-ray spectrum of rotating-gantry micro-CT machines, without opening or modifying the machine, may be of particular interest to researchers that wish to perform dual-energy computed tomography (DECT) or provide enhanced contrast to certain objects within a sample.

We demonstrate a methodology for the production of custom sized and varying composition in-bore x-ray filters that surround a CT bed and sample during scanning. In our particular case, we demonstrate the effectiveness of the methodology by producing an erbium-embedded resin filter, for use with a commercial micro-CT scanner (eXplore speCZT, GE Healthcare). Feasibility is demonstrated by implementing the filter technology with an erbium-based vascular perfusion contrast agent to provide DECT composition analysis of a perfused rat hindlimb.

Using decomposition algorithms developed in-house, we successful decompose a rat hindlimb (perfused with our custom contrast agent and scanned at two energies) into its respective perfused vascular and bone components. In the future, this technique for filter preparation can be applied for a variety of elemental compositions depending on the users' needs, thereby expanding applications for DECT on rotating-gantry micro-CT machines.

9412-65, Session 13

Detector, collimator and real-time reconstructor for a new scanning-beam digital x-ray (SBDX) prototype

Michael A. Speidel, Michael T. Tomkowiak, Amish N. Raval, David A. P. Dunkerley, Jordan M. Slagowski, Univ. of Wisconsin-Madison (United States); Paul Kahn, Chwen-Yuan Ku, Tobias Funk, Triple Ring Technologies, Inc. (United States)

Scanning-beam digital x-ray (SBDX) is an inverse geometry fluoroscopy system for low dose cardiac imaging. While high dose efficiency is achieved through the use of a narrow scanned x-ray beam which minimizes detected x-ray scatter, the use of tight beam collimation limits the maximum achievable x-ray fluence. To increase the fluence available for cine-quality angiographic imaging, we have constructed a new SBDX prototype with a wider x-ray beam, larger-area detector, and new real-time image reconstructor. Imaging is performed with a scanning source that generates 40,328 narrow overlapping projections from 71 x 71 focal spot positions for every 1/15 s scan period. A high speed 2-mm thick CdTe photon counting detector was constructed with 320x160 elements and 10.6 cm x 5.3 cm area (full readout every 1.28 microsec), providing an 86% increase in area over the previous SBDX prototype. A matching multihole collimator was fabricated from layers of tungsten, brass, and lead, and a multi-GPU reconstructor was assembled to reconstruct the stream of captured detector images into full field-of-view images in real time. Thirty-two tomosynthetic planes spaced by 5mm plus a multiplane composite image are produced for each scan frame. Noise equivalent quanta on the new SBDX prototype measured 63%-71% higher than the previous prototype. X-ray scatter fraction was 3.2-7.8% when imaging 18.6-32.6 cm acrylic phantoms, versus 1.8-4.2% with the previous prototype. Coronary angiographic imaging at 15 frame/s was successfully performed on the new SBDX prototype, with live display of either a multiplane composite or single plane image.

9412-66, Session 13

Electronic versus mechanical phase stepping in phase-contrast x-ray imaging

Katherine Harmon, Houxun Miao, Andrew A. Gomella, Eric E. Bennett, Alirexa Panna, Harold H. Wen, National Institutes of Health (United States)

Grating-based x-ray Talbot-Lau Interferometers provide information on the refractive index variation in the sample in addition to the classic attenuation contrast. To quantify the phase distribution of the x-ray wavefront after propagation through the sample, mechanical phase-stepping (MPS), where a grating is moved multiple steps within a period, is a well-established method in optical wavefront measurements. Recently, electronic phase-stepping (EPS) together with an adaptive algorithm have been developed to measure the x-ray wavefront without moving parts. A periodic intensity modulation (fringes), obtained in this study via a Talbot-Lau interferometer, is introduced to the projection image. A change in the phase-distribution of the x-ray wavefront occurs as the x-rays pass through a sample and is detected as variations of the fringe pattern. In MPS, the fringe pattern is stepped across the image by moving a grating to retrieve the phase information. In the alternative EPS, the sample projection image and the fringes move relative to each other by electronically shifting the x-ray focal spot of the source. Here we provide a quantitative comparison between MPS and EPS to show that they yield the same results. The EPS is implemented in phase-contrast studies for the benefit of precision, speed, and lower cost relative to MPS, while achieving the same outcomes.

9412-67, Session 13

Digital breast tomosynthesis with minimal breast compression

David A. Scaduto, Min Yang, Wei Zhao, Stony Brook Univ. (United States)

Breast compression is utilized in mammography to improve image quality and reduce radiation dose. Lesion conspicuity is improved by reducing scatter effects on contrast and by reducing the superposition of tissue structures. However, patient discomfort due to breast compression has been cited as a potential cause of noncompliance with recommended screening practices. Further, compression may also occlude blood flow in the breast, complicating imaging with intravenous contrast agents and preventing accurate quantification of contrast enhancement and kinetics. Previous studies have investigated reducing breast compression in planar mammography and digital breast tomosynthesis (DBT), though this typically comes at the expense of degradation in image quality or increase in mean glandular dose (MGD). We propose to optimize the image acquisition technique for reduced compression in DBT without compromising image quality or increasing MGD. A previously validated cascaded linear system model for DBT is employed to optimize imaging parameters for maximum lesion conspicuity using the ideal signal-to-noise ratio d' normalized to unit dose as the figure-of-merit. Phantom images are acquired on a prototype DBT system using the optimized imaging parameters and are assessed for image quality and lesion conspicuity. Data from these phantom studies are used to refine the cascaded linear system model to further optimize imaging technique.

9412-68, Session 13

A dual-detector fluoroscopy system for interventional radiology

Christopher W. Ellenor, Paul Kahn, Oleg J. Konings, Chwen-Yuan Ku, Triple Ring Technologies, Inc. (United States); Rebecca Fahrig, Stanford Univ. (United States); Tobias Funk, Triple Ring Technologies, Inc. (United States)

Interventional radiology (IR) has been extremely successful in treating many diseases and medical conditions with minimal invasiveness. However, X-ray dose to the patient and the physician is of concern.

It has been demonstrated that the scanning beam digital X-ray (SBDX) system can significantly reduce dose in interventional procedures. The existing SBDX system is geared towards interventional cardiology and lacks the field of view (FOV) necessary for interventional radiology.

We have designed and constructed a novel X-Ray scanner for interventional radiology based on the SBDX technology. The new system employs the multifocal X-ray tube of the existing SBDX system. The single detector has been replaced by two small detectors that are spaced laterally. These modifications lead to a significantly larger FOV in one dimension compared to the existing SBDX system.

We have measured the size of the FOV at various positions around isocenter by imaging a lead ruler at different distances from the X-ray source.

At the system isocenter (depth 45cm measured from the X-ray focal spots), we measure an FOV of 32cm, and at depths of 35 and 55cm we measure FOVs of 29.5 and over 34cm respectively. The FOV is 1.7 times that of the cardiology system at a depth of 35cm, and more than double at depths of 45 and 55cm.

We successfully increased the FOV of the existing SBDX system demonstrating the potential expansion of this novel technology into interventional radiology.

9412-69, Session 14

Task-driven imaging in cone-beam computed tomography

Grace J. Gang, Joseph W. Stayman, Sarah Ouadah, Johns Hopkins Univ. (United States); Tina Ehtiati, Siemens Healthcare (United States); Jeffrey H. Siewerdsen, Johns Hopkins Univ. (United States)

Purpose: Conventional workflow in interventional imaging often ignores a wealth of prior information of the patient anatomy and the imaging task. This work introduces a task-driven imaging framework that utilizes such information to prospectively design acquisition and reconstruction techniques for cone-beam CT (CBCT) in a manner that maximizes task-based performance in subsequent imaging procedures.

Methods: The framework is demonstrated in jointly optimizing tube current modulation, source-detector orbits, and reconstruction parameters for interventional brain imaging. Theoretical predictors of noise and resolution in both filtered-backprojection and model-based reconstruction relates acquisition and reconstruction parameters to task-based detectability. Given a patient-specific prior image and specification of the imaging task, an optimization algorithm prospectively identifies the combination of imaging parameters that maximizes task-based detectability.

Results: Optimization of tube current modulation and view-dependent reconstruction kernel was shown to have greatest benefits for a directional task (e.g., identification of device or tissue orientation). The task-driven approach yielded techniques in which the dose was concentrated and the kernel (or regularization parameter) was sharpest for views contributing the most to the signal power associated with the imaging task. For example, detectability of a high-frequency directional task in intracranial imaging was improved by at least 42% (d'=1.77) compared to conventional approaches (d'=1.02). Optimization of the source-detector orbit successfully avoided highly attenuating structures that can confound the imaging task by introducing noise correlations masquerading at spatial frequencies of interest.

Conclusions: This work demonstrated the potential of a task-driven imaging framework to improve image quality and reduce dose beyond that achievable with conventional imaging approaches.

9412-70, Session 14

The rotate-plus-shift C-arm trajectory: complete CT data with limited angular rotation

Ludwig Ritschl, Ziehm Imaging GmbH (Germany); Jan Kuntz, Marc Kachelriess, Deutsches Krebsforschungszentrum (Germany)

In the last decade C-arm-based cone-beam CT became a widely used modality for intraoperative imaging. Typically a C-arm scan is performed using a circle-like trajectory around a region of interest. Therefor an angular range of at least 180° plus fan-angle must be covered to ensure a completely sampled data set. This fact defines some constraints on the geometry and technical specifications of a C-arm system, for example a larger C radius or a smaller C opening respectively. These technical modifications are usually not benificial in terms of handling and usability of the C-arm during classical 2D applications like fluoroscopy. The method proposed in this paper relaxes the constraint of 180° plus fan-angle rotation to acquire a complete data set. The proposed C-arm trajectory requires a motorization of the orbital axis of the C and of ideally two orthogonal axis in the C plane. The trajectory consists of three parts: A rotation of the C around a defined iso-center and two translational movements parallel to the detector plane at the begin and at the end of the rotation. Combining these three parts to one trajectory enables for the acquisition of a completely sampled dataset using only 180° minus fan-angle of rotation. To evaluate the method we show animal and cadaver scans acquired with a mobile C-arm prototype. We expect that the

transition of this method into clinical routine will lead to a much broader use of intraoperative 3D imaging in a wide field of clinical applications.

9412-71, Session 14

Simultaneous imaging of multiple contrast agents using full-spectrum micro-CT

Darin P. Clark, Ctr. for In Vivo Microscopy (United States); Mengheng Touch, Medical Physics, Duke University (United States); William C. Barber, DxRay, Inc. (United States); Cristian T. Badea, Ctr. for In Vivo Microscopy (United States)

One of the major challenges for in vivo micro-computed tomography (CT) imaging is the poor contrast sensitivity. To increase contrast, exogenous contrast agents can be used as imaging probes. A natural extension is to introduce multiple probes that incorporate different high-Z materials that can be separated via spectral micro-CT, thus enabling functional or molecular imaging. Photon counting x-ray detectors (PCXD) allow energy-sensitive CT by reconstructing a series of images associated with different x-ray energies from a single scan. We implemented full-spectrum micro-CT using a PCXD and applied it to separate multiple k-edge contrast agents which are simultaneously present in an object (e.g. iodine, barium, and gadolinium) from water. Since the individual energy bins are nominally quite narrow and the photon flux (dose) should be controlled, projection data are very noisy, particularly at high and low energies relative to the source spectrum. The noise in such data is further amplified when performing post-reconstruction material decomposition. Here, we propose and demonstrate a novel post-reconstruction filtration scheme which drastically improves the contrast-to-noise ratio in full-spectrum micro-CT data and resultant material decompositions. Specifically, we performed spectrally local and global bilateral filtration in tandem within the split Bregman framework, producing results which are both spectrally smooth and structurally coherent. We performed experiments using both digital and physical calibration phantoms. The average maximum contrast-to-noise ratio increase by filtration is 13.35-times higher than in filtered backprojection (FBP) images. The average relative error in measuring the concentrations was 21%. A comparison between measured and estimated spectral responses points toward inaccuracies associated with PXCDs which will require further corrections to perform material decomposition with high sensitivity and accuracy.

9412-72, Session 14

Spectral deblurring: an algorithm for high-resolution, hybrid spectral CT

Darin P. Clark, Cristian T. Badea, Ctr. for In Vivo Microscopy (United States)

We are developing a hybrid, dual-source micro-CT system based on the combined use of an energy integrating (EID) x-ray detector and a photon counting x-ray detector (PCXD). PCXDs have the potential to reduce radiation dose and to enable novel imaging applications such as functional and molecular CT imaging. However, the spatial resolution achievable with PCXDs is limited since pixel size is often larger to deal with charge sharing effects. To address this problem, we propose spectral diffusion—a novel, iterative reconstruction algorithm for increasing spatial resolution in hybrid, spectral micro-CT. At the heart of algorithm is the assumption that the underlying CT data to be reconstructed is piece-wise constant. Signals of this type can be robustly recovered in the presence of noise by enforcing gradient sparsity during iterative reconstruction. We have performed simulations using the virtual MOBY mouse phantom to assess the limits of the algorithms deblurring capabilities. Our simulations were used in a feasibility study focused on molecular imaging of atherosclerotic plaque using activatable iodine and gold nanoparticles. The results indicate that accurate estimation of material concentrations and an increase of spatial

resolution resolution can be achieved when the pixel size ratio between the PCXD and EID is 5:1, but it becomes inadequate at 10:1. An accurate sub-pixel registration and a known relationship between reconstructed intensities of the two imaging chains is essential for the success of this algorithm.

9412-73, Session 14

Performance comparison between static and dynamic cardiac CT on perfusion quantitation and patient classification tasks

Michael D. Bindschadler, Univ. of Washington (United States); Dimple Modgil, The Univ. of Chicago (United States); Kelley R. Branch, Univ. of Washington (United States); Patrick J. La Rivière, The Univ. of Chicago (United States); Adam M. Alessio, Univ. of Washington (United States)

Cardiac CT acquisitions for perfusion assessment can be performed in a dynamic or static mode. In this simulation study, we evaluate the relative classification and quantification performance of these modes for assessing myocardial blood flow (MBF). In the dynamic method, a series of low dose cardiac CT acquisitions yields data on contrast bolus dynamics over time; these data are fit with a model to give a quantitative MBF estimate. In the static method, a single, higher dose CT acquisition is obtained, and the relative CT numbers in the myocardium are used to infer perfusion states. The static method does not directly yield a quantitative estimate of MBF, but these estimates can be obtained by introducing assumed linear relationships between CT number and MBF, consistent with the ways such images are typically visually interpreted. Data obtained by either method may be used for a variety of clinical tasks, including 1) stratifying patients into differing categories of ischemia and 2) using the quantitative MBF estimate directly to evaluate ischemic disease severity. Through simulations, we evaluate the performance on each of these tasks. The dynamic method has very low bias in MBF estimates, making it particularly suitable for quantitative estimation. At matched radiation dose levels, ROC analysis demonstrated that the static method, with its high bias but generally lower variance, has superior performance in stratifying patients, especially for larger patients.

9412-74, Session 15

Data truncation in multi-contrast tomosynthesis image reconstructions

John W. Garrett, Yongshuai Ge, Ke Li, Guang-Hong Chen, Univ. of Wisconsin-Madison (United States)

Differential phase contrast imaging is a promising new image modality that utilizes the refraction rather than the absorption of x-rays to image an object. A Talbot-Lau interferometer may be used to permit differential phase contrast imaging with a conventional medical x-ray source and detector. However, the current size of the gratings fabricated for these interferometers are often relatively small. As a result, data truncation image artifacts are often observed in a tomographic acquisition and reconstruction. When data are truncated in x-ray absorption imaging, the methods have been introduced to mitigate the truncation artifacts. However, the same strategy to mitigate absorption truncation artifacts may not be appropriate for differential phase contrast or dark field tomographic imaging. In this work, several new methods to mitigate data truncation artifacts in a multi-contrast imaging system have been proposed and evaluated for tomosynthesis data acquisitions. The proposed methods were validated using experimental data acquired for a bovine udder as well as several cadaver breast specimens using a benchtop system at our facility.

9412-75, Session 15

Feasibility study of the diagnosis and monitoring of cystic fibrosis in pediatric patients using stationary digital chest tomosynthesis

Marci Potuzko, Jing Shan, Caleb Pearce, Yueh Z. Lee, Jianping Lu, Otto Zhou, The Univ. of North Carolina at Chapel Hill (United States)

Cystic fibrosis is a disease affecting approximately 70,000 people worldwide. This disease, characterized by inflammation and changes in lung structure and function, begins early in life, and is monitored by a lifetime of yearly CT scans with high radiation doses. The more radiosensitive nature of children combined with their lack of ability to lay prone and perform a breath-hold leads to a void in the availability of diagnostic tests suitable for infants and preschoolers. Currently CT is used to image CF patients, although tomosynthesis is capable of doing this at a lower dose. CT has an isotropic resolution of 0.25-1mm, and while digital tomosynthesis has poorer depth resolution, 1mm, its spatial resolution is superior at 0.2mm. In addition, the dose of a full chest tomosynthesis scan is 0.1mSv, as compared to approximately 1.5-2mSv for a low-dose CT. Even at reduced dose protocols typically used for CF patients, the CT dose is approximately 0.55mSv. Previous studies have evaluated tomosynthesis as a method to monitor CF, but did not evaluate children younger than 8 years old, as long scan times can necessitate pediatric patients to be sedated for imaging. We seek to prevent this by using our stationary digital chest tomosynthesis system, and investigate performing a full scan in approximately 2s while maintaining image quality. Thus far we have imaged ex vivo lung phantoms that have been implanted with a mucus substitute in order to mimic CF symptoms.

9412-76, Session 15

Segmentation methods for breast vasculature in dual-energy contrast-enhanced digital breast tomosynthesis

Kristen C. Lau, Tanushriya Singh, Hyo Min Lee, Andrew D. A. Maidment, The Univ. of Pennsylvania Health System (United States)

Dual-energy contrast-enhanced digital breast tomosynthesis (DE CE-DBT) uses an iodinated contrast agent to image the three-dimensional breast vasculature. The University of Pennsylvania has an ongoing DE CE-DBT clinical study in patients with known breast cancers. The breast is compressed continuously and imaged at 4 time points (1 pre-contrast; 3 post-contrast). DE images are obtained by a weighted logarithmic subtraction of the high-energy (HE) and low-energy (LE) image pairs. Temporal subtraction of the post-contrast DE images from the pre-contrast DE image is performed to analyze iodine uptake. We have developed a method for segmenting the breast vasculature in CE-DBT images. Anisotropic diffusion filtering and Gabor filtering were used for enhancement of vessel features. Threshold and binary graph cut methods were used to label vessel and background features successfully. Statistical and clinical evaluations of segmentation accuracy in DE-CBT images are ongoing.

9412-77, Session 15

Initial clinical evaluation of stationary digital breast tomosynthesis

Jabari Calliste, Andrew W. Tucker, Emily Gidcumb, Cherie M. Kuzmiak, Jianping Lu, Otto Zhou, Yueh Z. Lee, The Univ. of North Carolina at Chapel Hill (United States)

Full field digital mammography (FFDM) has been the gold-standard for breast imaging. It effectively detects the presence, distribution, and morphology of microcalcifications (MC), helping predict the likelihood of malignancy. Digital breast tomosynthesis (DBT) has overcome some limitations of FFDM such as poor sensitivity, specificity, and positive predictive values due to the 2D superimposition of breast tissue structures, especially in dense breast tissue. The current commercial continuous motion DBT scanners are however ineffective in MC detection due to lower spatial resolution, compared to FFDM. Mechanical motion of the x-ray source creates focal spot blur, producing an anisotropic and elongated focal spot.

We have developed a stationary breast tomosynthesis system (s-DBT) using a carbon nanotube (CNT) X-ray source array. The CNT array is electronically controlled, allowing for the acquisition of projection images in rapid succession over a large angular span, with zero tube motion. Using physical phantoms and human breast specimens, this system has demonstrated higher spatial resolution than continuous motion DBT.

The objective of this study is to compare the diagnostic clinical performance of s-DBT to that of FFDM. Under UNC's institutional review board regulations, 100 patients with known breast lesions are currently being recruited and imaged with both FFDM and s-DBT. A reader study will be conducted on the collected data, comparing the diagnostic accuracy of s-DBT compared to FFDM. We have successfully imaged the first 15 patients, and initial results indicate that s-DBT produces comparable MC sharpness, and increased lesion conspicuity compared to FFDM.

9412-78, Session 15

The impact of breast structure on lesion detection in breast tomosynthesis

Nooshin Kiarashi, Loren W. Nolte, Duke Univ. (United States); Joseph Y. Lo, William P. Segars, Sujata V. Ghate, Ehsan Samei, Duke Univ. School of Medicine (United States)

Virtual clinical trials (VCT) can be carefully designed to inform, orient, or potentially replace clinical trials. The focus of this study was to demonstrate the capability of the sophisticated tools that can be used in the design, implementation, and performance analysis of VCTs, through characterization of the effect of background tissue density and heterogeneity on the detection of irregular masses in digital breast tomosynthesis. Twenty breast models from the extended cardiac-torso (XCAT) family, generated based on dedicated breast computed tomography of human subjects, were used to extract a total of 2173 volumes of interest (VOI) from simulated tomosynthesis images. Five different lesions, modeled after human subject tomosynthesis images, were embedded in the VOIs. Effects of background tissue density and heterogeneity on the detection of the lesions were studied by implementing a doubly composite hypothesis signal detection theory paradigm with lesion location known exactly, lesion known exactly or statistically, and background known statistically. The results indicated that the detection performance as measured by the area under the receiver operating characteristic curve deteriorated as density was increased, yielding findings consistent with clinical studies. The detection performance varied substantially across the twenty breasts. Furthermore, the log-likelihood ratio under H1 and H0 seemed to be affected by background tissue density and heterogeneity differently. Considering background tissue variability can change the outcomes of a VCT and is hence of crucial importance. The XCAT breast phantoms can address this concern by offering realistic modeling of background tissue variability based on a wide range of human subjects.

9412-79, Session 15

Circular tomosynthesis for neuro perfusion imaging on an interventional C-arm

Bernhard E. H. Claus, David A. Langan, Omar Al Assad, Xin Wang, GE Global Research (United States)

There is a clinical need to improve cerebral perfusion assessment during the treatment of ischemic stroke in the interventional suite. The clinician is able to ascertain the arterial blockage was successfully opened but is unable to sufficiently assess blood flow through the parenchyma. C-arm spin acquisitions can image the cerebral blood volume but are challenged to capture the temporal dynamics of the iodinated contrast bolus. Here we propose to utilize a circular tomosynthesis (tomo) acquisition on the C-arm to achieve the necessary temporal sampling of the volume at the cost of incomplete data. We address the incomplete data problem via compressed sensing and incorporate parametric flow models (4D reconstruction) to improve our temporal resolution. A CT neuro perfusion data set is utilized for generation of a dynamic (4D) volumetric model from which the tomo projections are generated. The 4D model is also used as a ground truth reference for performance evaluation. The performance that may be achieved with the tomo acquisition and 4D reconstruction (under simulation conditions, i.e., without considering data fidelity limitations due to imaging physics and imaging chain) is evaluated. In the considered scenario, good agreement between the ground truth and the tomo reconstruction in the parenchyma was achieved.

9412-80, Session PSMon

NSECT sinogram sampling optimization by normalized mutual information

Rodrigo S. Viana, Univ. de São Paulo (Brazil); Miguel A Galarreta-Valverde, University of São Paulo (Brazil); Choukri Mekkaoui, Harvard Medical School (United States) and Massachusetts General Hospital (United States); Hélio Yoriyaz, Marcel P. Jackowski II, Univ. de São Paulo (Brazil)

Neutron Stimulated Emission Computed Tomography (NSECT) is an emerging noninvasive imaging technique that measures the distribution of isotopes from biological tissue using fast-neutron inelastic scattering reaction. As a high-energy neutron beam illuminates the sample, the excited nuclei emit gamma rays whose energies are unique to the emitting nuclei. Tomographic images of each element in the spectrum can then be reconstructed to represent the spatial distribution of elements within the sample using a first generation tomographic scan. NSECT's high radiation dose deposition, however, requires a sampling strategy that can yield maximum image quality under a reasonable radiation dose. In this work, we introduce an NSECT sinogram sampling technique based on the Normalized Mutual Information (NMI) of the reconstructed images. By applying the Radon Transform on the ground-truth image obtained from a carbon-based synthetic phantom, different NSECT sinogram configurations were simulated and compared by using the NMI as a similarity measure. The proposed methodology was also applied on NSECT images acquired using MCNP5 Monte Carlo simulations of the same phantom to validate our strategy. Results show that NMI can be used to robustly predict the quality of the reconstructed NSECT images, leading to an optimal NSECT acquisition and a minimal absorbed dose by the patient.

9412-81, Session PSMon

Feasibility study of dose reduction in digital breast tomosynthesis using non-local denoising algorithms

Marcelo A. C. Vieira, Polyana F. Nunes, Helder C. R. Oliveira, Lucas R. Borges, Univ. de São Paulo (Brazil); Predrag R. Bakic, Raymond J. Acciavatti, The Univ. of Pennsylvania Health System (United States); Bruno Barufaldi, Univ. de São Paulo (Brazil); Andrew D. A. Maidment, The Univ. of Pennsylvania Health System (United States)

Digital Breast Tomosynthesis (DTB) is a novel x-ray medical imaging modality in which a limited number of low dose projections from a narrow angular range are acquired as the x-ray tube moves over an arc. A 3D volume is reconstructed from these projections and tomographic sections of the breast are generated. The advantage over 2D digital mammography is that tomosynthesis reduces the tissue overlap. Currently, the Food and Drug Administration (FDA) allows the clinical use of DBT in the United States in "combo-mode", in which, in addition to DBT projections, a 2D mammogram is taken with the standard radiation dose. As a result, the patient is exposed to radiation doses higher than used in mammography. Efforts to reduce the radiation dose in DBT examinations are of great interest. However, a decrease in dose leads to an increased quantum noise level, and related decrease in image quality. This work is aimed at addressing this problem by the use of denoising techniques, which could allow for dose reduction while keeping the image quality acceptable. We have studied the "state of the art" denoising techniques for filtering the quantum noise due to the reduced dose in DBT projections. We acquired DBT projections at different dose levels of an anthropomorphic physical breast phantom with inserted simulated microcalcifications. Selected quantitative measures of image quality were used to estimate the percentage of dose reduction that, in combination with non-local denoising techniques, would produce the comparable image quality as those acquired with full radiation dose.

9412-82, Session PSMon

Virtual clinical trials using inserted pathology in clinical images: investigation of assumptions for local glandularity and noise

Alaleh Rashidnasab, Univ. of Surrey (United Kingdom) and KU Leuven (Belgium); Premkumar Elangovan, Univ. of Surrey (United Kingdom); David R. Dance, Univ. of Surrey (United Kingdom) and NCCPM, The Royal Surrey County Hospital NHS Trust (United Kingdom); Kenneth C. Young, NCCPM, The Royal Surrey County Hospital NHS Trust (United Kingdom) and Univ. of Surrey (United Kingdom); Kevin Wells, Univ. of Surrey (United Kingdom)

Virtual clinical trials are a viable alternative to clinical trials for testing and comparing the performance of breast imaging systems. One of the main simulation methodologies used in virtual trials employs clinical images of patients in which simulated models of cancer are inserted using a physics-based template multiplication technique. The purpose of this work is to investigate two assumptions commonly considered in this simulation approach. Given the absence of useful depth information in a clinical situation, an average measure of the local breast glandularity is commonly used as an estimate of the breast composition at the insertion site. Also, it is assumed that change in the relative noise in the image at the insertion site after insertion of a mass is negligible. In order to test the validity of these assumptions, spheres representing idealised masses and anthropomorphic computational breast phantoms with perfect prior knowledge of local tissue composition and distribution were used. Results showed less variation in the contrast obtained from the template multiplication insertion method compared to the true contrast values obtained from voxel replacement in the heterogeneous phantom due to loss of depth-wise tissue distribution. It was also found that the amount of noise is underestimated by insertion of spherical masses using template multiplication method by 3%- %20 compared to voxel replacement for the test conditions, however this resulted in less than 6% variation in CNR compared to CNR by voxel replacement.

9412-83, Session PSMon

Region of interest processing for iterative reconstruction in x-ray computed tomography

Felix K. Kopp, Radin A. Nasirudin, Kai Mei, Andreas Fehringer, Franz Pfeiffer, Ernst J. Rummeny, Peter B. Noël, Technische Univ. München (Germany)

The recent advancements in the graphics card technology raised the performance of parallel computing and contributed to the introduction of iterative reconstruction methods for x-ray computed tomography in clinical CT scanners. Iterative maximum likelihood (ML) based reconstruction methods are known to reduce image noise and to improve the diagnostic quality of low-dose CT. However, iterative reconstruction of a region of interest (ROI), especially ML based, generates slices with unacceptable diagnostic quality. But for some clinical procedures, like cardiac CT, only a ROI is needed for diagnostics. A high-resolution reconstruction of the full field of view (FOV) consumes unnecessary computation effort that results in a slower reconstruction than clinically acceptable. In this work, we present an extension and evaluation of existing ROI processing algorithms. Especially improvements for the equalization between regions inside and outside of ROI are proposed. The evaluation was done on data collected from a clinical CT scanner. The performance of the different algorithms is qualitatively and quantitatively assessed. Our solution to the ROI problem provides an increase in signal-to-noise ratio and leads to less and more homogenous noise in the final reconstruction. The reconstruction speed of our technique was observed to be comparable with other previous proposed techniques. The development of ROI processing algorithms in combination with iterative reconstruction will provide higher diagnostic quality in the near future.

9412-84, Session PSMon

Improving low-dose cardiac CT images using 3D sparse representation based processing

Luyao Shi, Yang Chen, Limin Luo, Southeast Univ. (China); Guang-Hong Chen, Univ. of Wisconsin-Madison (United States)

Cardiac computed tomography (CCT) is a reliable and accurate tool for the diagnosis or exclusion of coronary artery disease and is also frequently used to guide the surgery. However, the radiation doses delivered to patients during X-ray CT examinations are relatively high when compared to other radiological examinations. Low-dose scans should thus be considered in order to avoid the harm of accumulative X-ray radiation. However, low dose CT (LDCT) images tend to be degraded by quantum noise and streak artifacts. Accordingly, in this paper, 3D sparse representation (3D SR) based processing is proposed to improve the cardiac LDCT image quality. Information on both spatial and temporal structure continuity is exploited in sparse representation with the aim of giving improved processing. Experiments on clinical data validate the good performance of the proposed method for improving the LDCT image quality. The proposed 3D SR approach leads to processed LDCT images with both effective noise/artifact suppression and good tissue details preservation. The quality of the processed LDCT images is visually comparable to the reference SDCT images. With the help of the second generation SIEMENS dual-source CT to obtain low-dose CT images, the radiation dose for a single patient during the cardiac CT scan can be reduced to less than 0.5 mSv while maintaining image quality.

9412-87, Session PSMon

Complete optical stack modeling for CMOS-based medical x-ray detectors

Alexander S. Zyazin, Inge M. Peters, Teledyne DALSA (Netherlands)

We have developed a simulation tool for modeling the performance of CMOS-based medical X-ray detectors, based on Monte Carlo toolkit GEANT4. Following the Fujita-Lubberts-Swank approach recently reported by Star-Lack et al., we calculate MTF(f), NPS(f) and DQE(f) curves. The complete optical stack is modeled, including scintillator, fiber optic plate (FOP), optical adhesive and CMOS image sensor. For critical parts of the stack, detailed models have been developed, taking into account their respective microstructure. This includes two different scintillator types: Gd_2O_2S:Tb (GOS) and CsI:Tl. The granular structure of the former is modeled using anisotropic Mie scattering. The columnar structure of the latter is introduced into calculations directly, using parameterization capabilities of GEANT4. The underlying homogeneous CsI layer is also incorporated into the model as well as the optional reflective layer on top of the scintillator screen or the protective polymer top coat. The FOP is modeled as an array of hexagonal bundles of fibers. The simulated CMOS stack consists of layers of Si_3N_4 and SiO_2 on top of a silicon pixel array. The model is validated against measurements of various test detector structures, using different X-ray spectra (RQA5 and RQA-M2), showing excellent match between calculated and measured MTF(f) and DQE(f) curves. Building upon validated components of the model, we can introduce changes into the optical stack architecture and predict the outcome of such changes with respect to the detector performance. We discuss a few examples in the paper.

9412-88, Session PSMon

Incorporating Corrections for the Head-Holder and Compensation Filter when Calculating Skin Dose during Fluoroscopically-Guided Interventions

Sarath Vijayan, Vijay K. Rana, Stephen Rudin, Daniel R. Bednarek, Toshiba Stroke and Vascular Research Ctr. (United States)

The skin dose tracking system (DTS) that we developed provides a color-coded illustration of the cumulative skin dose distribution on a 3D graphic of the patient during fluoroscopic procedures for immediate feedback to the interventionist. To improve the accuracy of dose calculation, we now have incorporated two additional important corrections (1) for the holder used to immobilize the head in neuro-interventions and (2) for the built-in compensation filters used for beam equalization. Both devices have been modeled in the DTS software so that beam intensity corrections can be made. The head-holder is modeled as two hemi-cylindrical surfaces such that the path length between those surfaces can be determined for rays to individual points on the skin surface. The head-holder on the imaging system we used was measured to attenuate the primary x-rays by 10 to 20% for normal incidence, and up to 40% at non-normal incidence. In addition, three compensation filters of different shape are built into the collimator apparatus and were measured to have attenuation factors ranging from 58% to 99%, depending on kVp and beam filtration. These filters can translate and rotate in the beam and their motion is tracked by the DTS using the digital signal from the imaging system. When it is determined that a ray to a given point on the skin passes through the compensation filter, the appropriate attenuation correction is applied. These corrections have been successfully incorporated in the DTS software to provide a more accurate determination of skin dose.

9412-89, Session PSMon

An attempt to estimate out-of-plane lung nodule elongation in tomosynthesis images

Artur Chodorowski, Chalmers Univ. of Technology (Sweden) and Medtech West, Sahlgrenska Univ. Hospital, Gothenburg (Sweden); Jonathan Arvidsson, Christina Söderman, Angelica Svalkvist, Ase A. Johnsson, Magnus Båth, Sahlgrenska Univ. Hospital (Sweden)

In chest tomosynthesis (TS) the most commonly used reconstruction methods are based on Filtered Back Projection (FBP) algorithms. Due to the limited angular range of x-ray projections, FBP reconstructed data is typically associated with a low spatial resolution in the out-of-plane dimension. Lung nodule measures that depend on depth information such as 3D shape and volume are therefore difficult to estimate. In this paper the relation between features from FBP reconstructed lung nodules and the true out-of-plane nodule elongation is investigated and a method for estimating the out-of-plane nodule elongation is proposed. In order to study these relations a number of steps that include simulation of ellipsoidal-shaped nodules, insertion into synthetic data volumes, construction of TS-projections and FBP-reconstruction were performed. In addition, the same procedure was used to simulate nodules and insert them into clinical chest TS projection data. The reconstructed nodule data was then investigated with respect to in-plane diameter, out-of-plane elongation, and attenuation coefficient. It was found that the voxel value in each nodule increased linearly with nodule elongation, for nodules with a constant attenuation coefficient. Similarly, the voxel value increased linearly with in-plane diameter. These observations indicate the possibility to predict the nodule elongation from the reconstructed voxel intensity values. The method represents a quantitative approach to chest tomosynthesis that may be useful in future work on volume and growth rate estimation of lung nodules.

9412-90, Session PSMon

A wire scanning based method for geometric calibration of high resolution CT system

Ruijie Jiang, Guang Li, Ning Gu, Gong Chen, Shouhua Luo, Southeast Univ. (China)

This paper is about geometric calibration of the high resolution CT system. Geometric calibration refers to the estimation of a set of parameters that describe the geometry of the CT system. Such parameters are so important that a little error of them will degrade the reconstruction images seriously, so more accurate geometric parameters are needed in the higher-resolution CT systems. But conventional calibration methods are not accurate enough for the current high resolution CT system whose resolution can reach sub-micrometer or even tens of nanometers. In this paper, we propose a new calibration method which has higher accuracy and it is based on the optimization theory. The superiority of this method is that we build a new cost function which sets up a relationship between the geometrical parameters and the binary reconstruction image of a thin wire. When the geometrical parameters are accurate, the cost function reaches its maximum value. In the experiment, we scanned a thin wire as the calibration data and a thin bamboo stick as the validation data to verify the correctness of the proposed method. Comparing with the image reconstructed with the geometric parameters calculated by using the conventional calibration method, the image reconstructed with the parameters gotten by our method has less geometric artifacts, so it can verify that our method can get more accurate geometric calibration parameters. Although we calculated only one geometric parameter in this paper, the geometric artifacts are still eliminated significantly. And this method can be easily generalized to all the geometrical parameters calibration in fan-beam or cone-beam CT systems.

9412-91, Session PSMon

Reduction of iodinated contrast medium in CT: feasibility study

Radin A. Nasirudin, Kai Mei, Technische Univ. München (Germany); Felix K. Kopp, Technische Univ. München (Germany); Ernst J. Rummeny, Peter B. Noël, Technische Univ. München (Germany)

The usage of radiographic contrast medium (CM) enhances tissue contrast in CT images, thus aiding the detection of tumors and lesions that are otherwise difficult to be distinguished. The magnitude of enhancement is proportional to the amount of CM deposited the target organ. However, the usage of high-dosed iodinated CM poses health risks, ranging from mild side effects to serious complications such as contrast-induced nephropathy (CIN). This work presents a method that enables the reduction of CM dosage, without affecting the enhancement in the image. The technique proposed takes advantage of the additional spectral information provided by dual-energy CT (DECT). In the first step, we apply material decomposition technique on the projection data to discriminate iodine from other materials in the scanned object. Then, we estimated the noise of the decomposed image by calculating the Cramér-Rao lower bound of the parameter estimator. Finally, we iteratively reconstruct the enhanced image, using the spatial information of the iodine and the estimation of noise as an input of the maximum-likelihood iterative reconstruction algorithm. The resulting reconstruction shows a notably improved contrast of the iodine in the image in comparison to standard FBP. Quantitatively, the contrast-noise-ratio (CNR) improved by about factor 3. The preliminary results from our technique show the possibility of reducing the clinical dosage of iodine, without affecting the desired contrast enhancement in the image.

9412-92, Session PSMon

Parallel and accelerated computing method based on echo-memory GPGPU for virtual MRI scanning

Bin Kuang, Nini Rao, Dingyun Liu, Yongli Wan, Univ. of Electronic Science and Technology of China (China); Chaoming He, Siemens Shenzhen Magnetic Resonance Ltd. (China)

MRI simulator is a very useful tool to study and learn the MRI. However, most of MRI simulators are very time-consuming due to their grid computing frameworks. Although some parallel computing approaches have been used to improve their computational complexity, the efficiency is still far from satisfactory. In this paper, a novel general-purpose computing on graphics processing units (GPGPU) based parallel computing accelerated Bloch solver is presented to solve this problem. In the proposed scheme, the models including virtual object, inhomogeneity of static field, virtual sequence controller and parallelized magnetization computation kernel are optimized and designed to meet the requirement of the parallel computing framework given by the GPGPU. In addition, to balance the memory complexity which is introduced by the GPGPU and the parallel computing performance, Echo Memory Mode is designed to reduce the huge memory required by the GPU device. This solution can fit the MR scanning in a more natural way than the traditional pipe-line streams design. Several tests confirmed that high scale simulation can be run smoothly with high acceleration factor (165X) and the acceleration effect can improve the hundreds of times compared with traditional simulators. Thus, the proposed method can effectively accelerate the MRI simulator under the acceptable performances.

9412-93, Session PSMon

Physics-based modeling of computed tomography systems

Hanbean Youn, Ho Kyung Kim, Soohwa Kam, Seung Ho Kim, Ji Woong Park, Hosang Jeon, Pusan National Univ. (Korea, Republic of)

A theoretical model describing projections from a computed tomography system has been developed. The model is based on the interaction physics in each component consisting of the system: x-ray quanta attenuation and scattering through objects, x-ray quanta detection and secondary quantum gain in scintillators, optical quanta detection in photodiodes, and addition of electronic noise quanta. Image blur due to the finite-sized focal spot, x-ray scattering, and optical quanta crosstalk in detectors are also considered. With the developed model, the effects of system parameters on projection/ reconstructed image quality are demonstrated.

9412-94, Session PSMon

A novel CT-FFR method for the coronary artery based on 4D-CT image analysis and structural and fluid analysis

Kenji Hirohata, Akira Kano, Akihiro Goryu, Junichiro Ooga, Takuya Hongo, Shinya Higashi, Toshiba Corp. (Japan); Yasuko Fujisawa, Satoshi Wakai, Kazumasa Arakita, Yoshihiro Ikeda, Shigeo Kaminaga, Toshiba Medical Systems Corp. (Japan); Brian S. Ko, Sujith K. Seneviratne, Monash Cardiovascular Research Ctr., Monash Univ. (Australia)

CT-FFR is usually conducted based on fluid analysis in which a lumped parameter coronary vascular bed model is assigned to represent the impedance of the downstream coronary vascular networks absent in the computational domain for each coronary outlet. There are issues, however with this approach. How to consider the motion from heart contraction and relaxation during the cardiac cycle. How to identify the boundary conditions of coronary artery outlets. How to properly take vessel stiffness into consideration. We have developed a novel approach based on 4D-CT image tracking (registration) and structural and fluid analysis, to tackle these issues. In our approach we use the variation of deformation of vessels and the variation of volume of the aorta and left ventricle, mainly from 70 to 100% of cardiac phase, to identify the analysis conditions, such as boundary conditions and stiffness of vessels. We use a statistical estimation method based on a hierarchical Bayes model to integrate 4D-CT measurements and structural and fluid analysis data. Under the identified analysis conditions, we can conduct structural and fluid analysis to determine pressure, flow rate and CT-FFR. The consistency of this method has been verified a comparison of 4D-CT-FFR analysis results derived from five clinical 4D-CT datasets with invasive measurements of FFR. Additionally, phantom experiments of flexible tubes with/without stenosis using pulsating pumps, flow sensors and pressure sensors were performed. Our results show that the proposed 4D-CT-FFR analysis method has the potential to estimate the effect of coronary artery stenosis on the blood flow.

9412-95, Session PSMon

NVIDIA OptiX ray-tracing engine as a new tool for modelling medical imaging systems

Krzysztof Kacperski, Jakub Pietrzak, Marek Cieślar, Institute of Maria Sklodowska-Curie (Poland)

The most accurate technique to model the X- and gamma radiation path through a numerically defined object is the Monte Carlo simulation which follows single photons according to their interaction probabilities. A simplified and much faster approach, which just integrates total interaction probabilities along selected paths, is known as ray tracing. Both techniques are used in medical imaging for simulating real imaging systems and as projectors required in iterative tomographic reconstruction algorithms. These approaches are ready for massive parallel implementation e.g. on Graphics Processing Units (GPU), which can greatly accelerate the computation time at a relatively low cost.

In this paper we describe the application of the NVIDIA OptiX ray-tracing engine, popular in professional graphics and rendering applications, as a new powerful tool for X- and gamma ray-tracing in medical imaging. It allows the implementation of a variety of physical interactions of rays with pixel-, mesh- or nurbs-based objects, and recording any required quantities, like path integrals, interaction sites, deposited energies, and others. Using the OptiX engine we have implemented a code for rapid Monte Carlo simulations of Single Photon Emission Computed Tomography (SPECT) imaging, as well as the ray-tracing projector, which can be used in reconstruction algorithms. The engine generates efficient, scalable and optimized GPU code, ready to run on multi GPU heterogeneous systems. We have compared the results our simulations with the GATE package. With the OptiX engine the computation time of a Monte Carlo simulation can be reduced from days to minutes.

9412-96, Session PSMon

Feasibility of ray- and pixel-driven projector/back-projector in linear motion tomosynthesis

Sung-Hoon Choi, Hee-Joung Kim, Seung-Wan Lee, Young-Jin Lee, Ye-Seul Kim, Haeng-Hwa Lee, Yonsei Univ. (Korea, Republic of)

Algorithmic system modeling which includes a geometric motion of source, phantom, and detector for reconstructing the tomographic images is well-known in medical imaging field. Especially in a digital X-ray tomosynthesis system (DTS) which scans an object in limited angle, not a full 360-degree, an accurate system modeling should be derived to reconstruct an excellent cross sectional image. In order to reconstruct cross sectional images from a set of projection data produced in a prototype chest digital tomosynthesis (CDT), we modeled two different virtual projectors which produce the projection images for different angle views based on a linear motion CDT system. The projectors were derived by pixel-driven and ray-driven methods and both projectors had the same acquisition condition. The source and detector move linearly in opposite direction, pivoting a fixed center-of-rotation (COR) and scanning around a 3D Shepp-Logan phantom. The results indicated that both pixel-driven and ray-driven projectors showed similar performances. Moreover, the root-mean-square errors (RMSEs) between the referenced parallel line integral of phantom and the 0-degree projections acquired from pixel-driven and ray-driven schemes showed small values of 1.14, 0.46, 0.33, 0.86, and 0.71 for pixel-driven projector and 1.04, 0.51, 0.46, 0.78, and 0.67 for ray-driven projector at five regions-of-interest (ROIs). These demonstrate that the developed projectors had an excellent performance. Consequently, the pixel-driven and ray-driven projectors could be well-suited in the linear motion CDT system.

9412-98, Session PSMon

PET image reconstruction based on median nonlocal means induced prior incorporating anatomical side information

Qingfeng Hou, Taishan Medical Univ. (China); Jianhua Ma, Wufan Chen, Southern Medical Univ. (China)

In this paper, we porposed a median-NLM filtering induced (MNLMi) prior for PET image reconstruction. We also extended it to incorporate coregistered MRI anatomical information (AMNLMi). Simulated PET MRI data were used to test the proposed algorithms. Comparison with several well-established algorithms were carried out . The primary results illustrated the performance of the proposed algorithms. Currently, we only focused on coregistered PET and MRI images and tested one method. Implementation of other methods will be our future research topics.

9412-99, Session PSMon

A rapid parallelization of cone-beam projection and back-projection operator based on texture fetching

Lizhe Xie, School of Stomatology, Nanjing Medical Univ. (China); Yining Hu, Yang Chen, Southeast Univ. (China) and Key Lab. of Computer Network and Information Integration, Ministry of Education of China (China) and Ctr. de Recherche en Information Biomedicale Sino-Francais (France); Luyao Shi, Southeast Univ. (China); Guang-Hong Chen, Univ. of Wisconsin-Madison (United States)

Projection and back-projection are the most computational consuming parts in Computed Tomography (CT) reconstruction. Parallelization strategies using GPU computing techniques have been introduced, yet most of which focus on making the projection model more realistic, by bring in complex interpolation or geometric calculation, which is in fact a limitation to computing efficiency of parallelization. We in this paper present a new parallelization scheme for both projection and back-projection (especially for 3D cases). The proposed method is based on CUDA technology carried out by NVIDIA Corporation. Instead of build complex model, we aimed on optimize the existing algorithm and make it suitable for CUDA implementation so as to gain fast computation speed. We make use of texture memory, which has faster access speed compare to global video memory. Texture fetching technique is applied for fast computation of linear interpolation, which is the main computation cost in both projection and back-projection. Besides linear interpolation, kernel convolution is also considered in the proposed method, based on texture memory, which is effective in artifacts suppression in the reconstructions. Besides the optimization to memory access mode, we use fixed sampling numbers in the computation of projection, which ensures the synchronization of blocks and threads, thus prevents the latency caused by inconsistent computation complexity. Experiment results have proven the computational efficiency and imaging quality of the proposed method.

9412-100, Session PSMon

Using digital subtraction in computer simulated images as a tool to aid the visual detection of masked lesions in dense breasts

Homero Schiabel, Luciana T. Guimaraes, Maria Angelica Z. Sousa, Univ. de São Paulo (Brazil)

This work proposes a simulation model involving subtraction of digital mammography images obtained at different X-ray beam levels of energy to aid the detection of breast malignant lesions. Absorption coefficients behavior of 3 main structures of clinical interest – adipose tissue, fiber glandular tissue and the typical carcinoma – as a function of the beam energy from a Mo X-ray tube was the basis to develop a computer simulation of the possible acquired images. The simulation has considered a typical compressed breast with 4.5cm in thickness, and variations of the carcinoma and glandular tissues thicknesses – 0.4 up to 2.0cm and 4.1 to 2.5cm, respectively – were evaluated as a function of the photons mean energy – 14 up to 25 keV, in the typical mammography energy range. Results have shown that: (a) if the carcinoma thickness is over 0.4cm, its detection may be feasible even masked by fiber tissue with exposures in the range of 19 to 25 keV; (b) for masked carcinoma with thickness in the range of 0.4-2.0cm, the proposed procedure can enhance it in the image resulting from the digital subtraction between images obtained at 14 and at 22 keV. Therefore such results indicate that this simulation procedure can be a useful tool in aiding the identification of possible missed malignant lesions which could not be detected in the typical exam, mainly considering dense breasts.

9412-101, Session PSMon

Optimized magnetic resonance diffusion protocol for ex-vivo whole human brain imaging with a clinical scanner

Benoit Scherrer, Onur Afacan, Aymeric Stamm, Boston Children's Hospital (United States) and Harvard Medical School (United States); Jolene Singh, Boston Children's Hospital (United States) and Harvard Medical School (United States); Simon K. Warfield, Boston Children's Hospital (United States) and Harvard Medical School (United States)

Diffusion-weighted magnetic resonance imaging (DW-MRI) enables non invasive investigation of the brain connectivity. However, for a number of pathologies such as sudden and unexpected death in epilepsy (SUDEP), the maximum achievable spatial resolution with today's conventional DW-MRI technology does not enable precise delineation of the connectivity of interest within a timeframe compatible with in vivo imaging. While the hippocampus, the insula and the brain stem are known to play a key role in the arousal system that may be altered in SUDEP, the precise assessment and delineation of the connectivity between them with has proven challenging in vivo. High-resolution postmortem DW-MRI examination with unlimited scan duration time may 1) provide a unique new understanding of the connectivity in this pathology and 2) enable the development of novel imaging biomarkers that will, with tomorrow's MR technology, enable in vivo prediction of the risk of SUDEP in the individual. Since animal scanners with a large bore size are not available to most researchers, human clinical scanners remain the best tool for ex-vivo imaging of whole brains. Ex-vivo fixation of tissues, however, alters tissue diffusivity profiles and creates the need for novel DW-MRI acquisition practices. In this work, we design an optimized protocol for ex vivo whole brain DW-MRI using a human clinical scanner by considering at each step the underlying physics of the MR acquisition process. Our optimized protocol may enable novel ex-vivo investigations with human clinical scanners at 3T which are widely available.

9412-102, Session PSMon

Design of an active pixel sensor based amorphous silicon with AIM-SPICE software

Belkacemi Siham, Zoubeida Hafdi, Univ. of Batna (Algeria)

In this paper, we present the Active Pixel Sensor (APS) studied and the results of DC and transient simulations with the software AIM-SPICE for the

study. This includes the variation of some parameters which are to study their effects on the functioning of the sensor.

9412-104, Session PSMon

Convolution-based estimation of organ dose in tube current modulated CT using patient-specific models

Xiaoyu Tian, William P. Segars, Duke Univ. (United States); Robert L. Dixon, Wake Forest Univ. (United States); Ehsan Samei, Duke Univ. (United States)

To accurately quantify the organ dose for individual patients, one needs to effectively model the patient anatomy and the dose field of the exam. However, the modeling of dose field can be challenging for TCM CT exams due to the heterogeneous distribution of scanner output radiation. The purpose of this work was to model the dose field for TCM CT exams using a convolution-based method. Such information was combined with a patient-matching technique and a validated Monte Carlo simulation program to establish a framework for accurate organ dose estimation.

The study included 60 adult computational phantoms (age range: 18–70 y.o.). For each patient model, organ dose under constant tube current was simulated using a validated Monte Carlo program for chest and abdominopelvic exams as the prediction basis. To model the dose field, the accumulated dose distribution profile was calculated using a convolution technique. The resulting dose distribution profile was used to generate organ and region-specific adjust factors that quantify the regional dose field. The organ dose was estimated by multiplying region-specific adjust factors with the organ dose coefficients estimated under constant tube current.

The proposed estimation method showed good accuracy with the organ dose simulated using TCM Monte Carlo program, with less than 10% error across all organs and modulation profiles.

This study developed an improved method for modeling the dose field under TCM scans. The result suggested the feasibility to prospectively and retrospectively estimate organ dose with patient anatomical information and specific TCM profiles.

9412-105, Session PSMon

Personalized low dose CT via variable kVp

Hui Wang, GE Global Research (China); Yannan Jin, GE Global Research (United States); Yangyang Yao, GE Global Research (China); Zhye Yin, GE Global Research (United States); Mingye Wu, Ming Yan, Kun Tao, GE Global Research (China); Bruno De Man, GE Global Research (United States)

Computerized Tomography (CT) is a powerful radiographic imaging technology but the health risk due to the exposure of x-ray radiation has drawn wide concern. In this study, we propose to use kVp modulation to reduce the radiation dose and achieve the personalized low dose CT. Two sets of simulation are performed to demonstrate the effectiveness of kVp modulation and the corresponding calibration. The first simulation used the helical body phantom (HBP) that is an elliptical water cylinder with high density bone inserts. The second simulation uses the NCAT phantom to emulate the practical use of kVp-modulation approach with region of interest (ROI) selected in the cardiac region. The kVp-modulation profile could be optimized view by view based on the knowledge of patient attenuation. A second order correction is applied to eliminate the beam hardening artifacts. To simplify the calibration process, we first generate the calibration vectors for a few representative spectra and then acquire other calibration vectors with interpolation. The simulation results demonstrate the beam hardening artifacts in the images with kVp modulation can be eliminated with proper beam hardening correction. The results also show

that the simplification of calibration did not impair the image quality: the calibration with the simplified and the complete vectors both eliminate the artifacts effectively and the results are comparable. In summary, this study demonstrates the feasibility of kVp modulation and gives a practical way to calibrate the high order beam hardening artifacts.

9412-106, Session PSMon

Dosimetry for spectral molecular imaging of small animals with MARS-CT

Noémie Ganet, CERN (Switzerland) and Univ. of Canterbury (New Zealand); Nigel Anderson, Univ. of Otago, Christchurch (New Zealand); Stephen Bell, MARS Bioimaging Ltd. (New Zealand); Anthony Butler, Univ. of Otago, Christchurch (New Zealand) and MARS Bioimaging Ltd. (New Zealand) and CERN (Switzerland); Phil H. Butler, Univ. of Canterbury (New Zealand) and MARS Bioimaging Ltd. (New Zealand) and CERN (Switzerland); Pierre Carbonez, CERN (Switzerland); Nicholas J. Cook, Medical Physics and Bio-Engineering, Canterbury District Health Board (New Zealand); Tony Cotterill, National Ctr. for Radiation Science, Institute of Environmental Science and Research (New Zealand); Steven Marsh, Univ. of Canterbury (New Zealand); Raj Kumar Panta, Univ. of Otago, Christchurch (New Zealand); John Laban, Sophie Walker, Adam Yeabsley, National Ctr. for Radiation Science, Institute of Environmental Science and Research (New Zealand); Jérôme Damet, CERN (Switzerland) and Institute of Radiation Physics, Univ. Hospital Lausanne (Switzerland)

The Medipix All Resolution Scanner (MARS) imaging system uses an x-ray detector chip operating in single photon counting mode for imaging small animals. The MARS system is unique in that it provides spectrometric information to facilitate differentiation of body tissue types. The MARS system has demonstrated exciting applications for small sample molecular imaging but the system's dosimetry has to be characterized before adaptation to human scale. This dosimetry study is performed using three phantoms each consisting of a 30 mm diameter homogeneous PMMA cylinder simulating a mouse. The imaging parameters used for this study are chosen to be equivalent to those used for a typical small animal study e.g. gold nanoparticle identification and location in mouse kidneys. Measurements of CTDI100 for small animal examinations are acquired with an Unfors Xi CT pencil chamber. Further dosimetry measurement are obtained with thermoluminescent Lithium Fluoride (LiF) detectors, calibrated in term of air kerma and placed at different depths in built phantoms. Continuous beam image acquisition results in a CTDI100 of 20.3 ± 1.0 mGy for a one minute rotation. A 3D reconstruction of the dose delivered to the TLD phantom is performed. The maximum dose is 20.7 ± 0.8 mGy. It is anticipated that optimisation of exposure settings and scanning protocols e.g. operating the scanner in pulsed mode, will significantly decrease dose. The procedures developed in this work will be used for future dosimetry calculations when optimizing image acquisition for the MARS system as it undergoes development towards full scale human clinical applications.

9412-107, Session PSMon

Patient specific tube current modulation for CT dose reduction

Yannan Jin, Zhye Yin, GE Global Research (United States); Yangyang Yao, Hui Wang, Mingye Wu, GE Global Research (China); Mannudeep K. Kalra, Massachusetts General Hospital (United States); Bruno De Man, GE Global Research (United States)

Radiation exposure during CT imaging has drawn growing concern from academia, industry as well as the general public. Sinusoidal tube current modulation has been available in most commercial product and used routinely in clinical practice. To further exploit the potential of tube current modulation, Sperl et al. proposed a Computer-Assisted Scan Protocol and Reconstruction (CASPAR) scheme [1] that modulates the tube current based on the clinical applications or patient specific information. The purpose of this study is to accelerate the CASPAR scheme to make it more practical for clinical use and investigate its dose benefit for different clinical applications. The Monte Carlo simulation in the original CASPAR scheme was substituted by the projection-based dose reconstruction to accelerate the optimization process. To demonstrate the dose benefit, we used the CATSIM package generate the projection data and perform standard FDK reconstruction. The NCAT phantom at thorax position was used in the simulation. We chose three clinical cases (chest scan, cardiac scan and breast-avoidance scan) and compared the dose level with different mA modulation schemes (patient specific, sinusoidal and constant mA) with matched image quality. The simulation study of three clinical cases demonstrated that the patient specific mA modulation could significantly reduce the radiation dose compared to the sinusoidal modulation available on current products. The dose benefits depend on the clinical application and object shape. With matched image quality, for chest scan the patient specific mA profile reduced the dose by about 15% compared to the sinusoid mA modulation; for the organ avoidance scan the dose reduction to the breast was over 50% compared to the constant mA baseline.

9412-108, Session PSMon

A real-time skin dose tracking system for biplane neuro-interventional procedures

Vijay K. Rana, Toshiba Stroke Research Ctr. (United States); Daniel R. Bednarek, Stephen Rudin, Toshiba Stroke and Vascular Research Ctr. (United States)

A biplane dose-tracking system (Biplane-DTS) that provides a real-time display of the skin-dose distribution on a 3D-patient graphic during neuro-interventional fluoroscopic procedures was developed. Biplane-DTS calculates patient skin dose using geometry and exposure information for the two gantries of the imaging system acquired from the digital system bus. The dose is calculated for individual points on the patient graphic surface for each exposure pulse and cumulative dose for both x-ray tubes is displayed as color maps on a split screen showing frontal and lateral projections of a 3D-humanoid graphic. Overall peak skin dose (PSD), FOV-PSD and current dose rates for the two gantries are also displayed. Biplane-DTS uses calibration files of mR/mAs for the frontal and lateral tubes measured with and without the table in the beam at the entrance surface of a 20 cm thick PMMA phantom placed 15 cm tube-side of the isocenter. For neuro-imaging, conversion factors are applied as a function of entrance field area to scale the calculated dose to that measured with a Phantom Laboratory head phantom which contains a human skull to account for differences in backscatter between PMMA and the human head. The software incorporates inverse-square correction to each point on the skin and corrects for angulation of the beam through the table. Dose calculated by Biplane DTS and values measured by a 6-cc ionization chamber placed on the head phantom at multiple points agree within a range of -3% to +7% with a standard deviation for all points of less than 3%.

9412-109, Session PSMon

A Monte Carlo study on the effect of the orbital bone to the radiation dose delivered to the eye lens

Andreas I. Stratis, KU Leuven (Belgium); Guozhi Zhang, UZ Leuven (Belgium); Reinhilde Jacobs, KU Leuven (Belgium) and UZ Leuven (Belgium); Ria Bogaerts, Hilde Bosmans, UZ Leuven (Belgium)

The anatomic position of the lens in the eyebulb indicates that a part of the radiation dose to the lens is due to backscatter from the intraorbital fat and the orbital bone. The aim of this study was to examine their impact on the lens dose in dental CBCT. A preliminary Monte Carlo (MC) study was conducted to estimate the amount of backscatter radiation due to the presence of a bone layer underneath a small tissue layer, to compare the Percentage Depth Dose (PDD) curves in tissue with and without the bone layer and estimate the distance from the bone-tissue interface where the influence of the bone is noticeable. Based on a head CT scan, an eye voxel phantom was designed using the DOSxyznrc code. Simulations were performed exposing the phantom at different x-ray energies under three different conditions: in air, in fat tissue and in real anatomy. The backscatter influence of tissue and bone on the lens dose was then estimated. The simulations were performed with the beam incident perpendicularly to the phantom. The results of the preliminary study showed a small decrease in BSFs when bone is present. The central axis PDD comparison showed that the reduction of the dose is more noticeable near the bone-tissue interface rather than closer to the surface. An average 9.25% increase in eye lens dose of the eye phantom due to backscatter from the tissue was observed while the orbital bone leads to a 1.5% decrease of scatter dose in the whole energy range.

9412-111, Session PSMon

Analysis of uncertainties in Monte Carlo simulated organ dose for chest CT

John S. Muryn, Cleveland State Univ. (United States); Ashraf G. Morgan, The Cleveland Clinic (United States); William P. Segars, Duke Univ. Medical Ctr. (United States); Christopher L. Liptak, Cleveland State Univ. (United States); Frank D. Dong, The Cleveland Clinic (United States); Andrew N. Primak, Siemens Medical Solutions USA, Inc. (United States); Xiang Li, Cleveland State Univ. (United States)

In Monte Carlo simulation of organ dose for a chest CT scan, many input parameters are required (e.g., half-value layer of the energy spectrum, effective beam width, and patient center position). These input parameters are provided by the manufacturer, measured experimentally, or determined based on typical clinical practices. The goal of this study was to assess the uncertainties in Monte Carlo simulated organ dose as a result of using input parameter values that deviate from the truth. Organ dose from a chest CT scan was simulated for a standard-size female phantom using a set of reference input parameter values (treated as the truth). To emulate the situation in which the input parameter values used by the researcher may deviate from the truth, additional simulations were performed in which errors were purposefully introduced into the input parameter values, the effects of which on organ dose were analyzed. Our study showed that errors in effective beam width of up to 3 mm had only a small effect (< 2.5%) on organ dose. In contrast, when the assumed anatomical center of the patient deviated from the true anatomical center by 5 cm, organ dose errors of up to 20% were introduced. Lastly, when the assumed extra scan length was longer by 4 cm than the true value, dose errors of up to 160% were found. The results answer the important question to what level of accuracy each input parameter needs to be determined in order to obtain accurate organ dose results.

9412-112, Session PSMon

A numerical investigation for the optimal positions and weighting coefficients of point dose measurements in the weighted CTDI

Jang-Hwan Choi, Stanford Univ. (United States); Dragos Constantin, Varian Medical Systems, Inc. (United States); Rebecca Fahrig, Stanford Univ. (United States)

The mean dose over the central phantom plane (i.e., z = 0, dose maximum image) is useful in that it allows us to compare radiation dose levels across different CT scanners and acquisition protocols. The mean dose from a conventional CT scan with table translation is typically estimated by weighted CTDI (CTDIw). However, the conventional CTDIw showed inconsistent performance, depending on its weighting coefficients ("1/2 and 1/2" or "1/3 and 2/3") and acquisition protocols.

We used a Monte Carlo (MC) model based on Geant4 (GEometry ANd Tracking) to generate dose profiles in the central plane of the CTDI phantom. MC simulations were carried out for three different sizes of z-collimator and different tube voltages (80, 100, or 120 kV), tube current of 80 mA, and exposure time of 25 ms.

We derived optimal weighting coefficients by taking integral of the radial dose profiles. The first-order linear equation and the quadratic equation were used to fit the dose profiles along the radial direction perpendicular to the central plane, and the fitted profiles were revolved along the Z-axis to compute the mean dose (i.e., total volume under the fitted profiles/ the central plane area). The linear equation integral brought the same equation as conventional CTDIW, and the quadratic equation integral brought new CTDIw incorporating different weightings ("2/3 and 1/3") and the middle dose point instead of the central dose point.

Compared to the results of MC simulations, our new CTDIw showed less error than the previous CTDIw methods by successfully incorporating the curvature of the dose profiles regardless of acquisition protocols. Our new CTDIw method will be also applicable to TG200/ICRU phantom which has a middle dose point.

9412-114, Session PSMon

3D dosimetry estimation for selective internal radiation therapy (SIRT) using SPECT/CT images: a phantom study

Senait A. Debebe, Florida International Univ. (United States); Juan Franquiz, Baptist Hospital of Miami (United States); Anthony J. McGoron, Florida International Univ. (United States)

Selective Internal Radiation Therapy (SIRT) is a common way to treat liver cancer that cannot be treated surgically. SIRT involves administration of Yttrium – 90 (90Y) microspheres via the hepatic artery after a diagnostic procedure using 99mTechnetium (Tc)-macroaggregated albumin (MAA) in order to detect extrahepatic shunting to the lung or the gastrointestinal tract. Accurate quantification of radionuclide administered to patients and radiation dose absorbed by different organs is of importance in SIRT. Accurate dosimetry for SIRT allows for optimization of dose delivery to the target tumor and may allow for the ability to assess the efficacy of the treatment. In this study, we proposed a method that can efficiently estimate radiation absorbed dose from 90Y bremsstrahlung SPECT/CT images of liver and the surrounding organs. Bremsstrahlung radiation from 90Y was simulated using scattering window of 99mTc (78keV at 57%). 99mTc images acquired at the photopeak energy window were used as a standard to examine the accuracy of dosimetry prediction by the simulated bremsstrahlung images. A Liqui-Phil abdominal phantom with liver, stomach and two tumor inserts was imaged using a Philips SPECT/CT scanner. The Dose Point Kernel convolution method was used to find the radiation absorbed dose at a voxel level for a three dimensional dose distribution. This method will allow for a complete estimate of the distribution of radiation absorbed dose by tumors, liver, stomach and other surrounding organs at voxel level. It provides a quantitative predictive method for SIRT treatment outcome and administered dose response for patients who undergo the treatment.

9412-115, Session PSMon

A comparison of mammographic systems for different breast thicknesses using model observer detectability

Nelis Van Peteghem, KU Leuven (Belgium); Elena Salvagnini, KU Leuven (Belgium) and SCK-CEN (Belgium); Hilde Bosmans, Lesley Cockmartin, Nicholas W. Marshall, UZ Leuven (Belgium)

This work investigated image quality as a function of PMMA thickness on a variety of mammography systems. Image quality was quantified by calculating detectability (d') using a non-prewhitening with eye filter model observer (NPWE). Routinely acquired quality control (QC) data for eleven digital radiography (DR) systems were analyzed, including two systems equipped with the Siemens PRIME upgrade and one system with the Claymount SmartBucky detector. The d' data were calculated for 0.1 and 0.25 mm diameter gold discs using homogeneous PMMA images taken from the routinely performed AEC test (PMMA thickness from 2 to 7 cm), the detector response function and the detector modulation transfer function (MTF). The GE Essential systems had the highest d' values for low thicknesses and the lowest d' values for high thicknesses. The Hologic Selenia Dimension systems had the most stable detectability curve, ensuring high d' values at high thicknesses. This was achieved by increasing the mean glandular dose (MGD) at higher thicknesses compared to the other systems. The Siemens PRIME and Claymount system detectability results were comparable to the standard FFDM systems. Mean glandular dose at 5, 6 and 7 cm PMMA and gold threshold thickness at 5 cm PMMA were also evaluated. The Claymount system had a high gold threshold thickness (T) compared to the other systems. This was probably caused by the low dose at which this DR detector operates.

9412-116, Session PSMon

Influence of DBT reconstruction algorithm on power law spectrum coefficient

Laurence Vancamberg, Ann-Katherine Carton, Ilyes Hadjabderrahmane, Giovanni J. Palma, Pablo Milioni de Carvalho, Răzvan Iordache, Serge L. Muller, GE Healthcare France (France)

In breast X-ray images, texture has been characterized by a noise power spectrum that has an inverse power-law shape described by its slope β in a log-log domain. The magnitude of this power law spectrum coefficient β has been shown to relate to lesion detectability. In this paper, we assessed β in reconstructed digital breast tomosynthesis images to evaluate its sensitivity to different typical reconstruction algorithms. A comparison with the β coefficient estimated from 2D DBT projections was also performed. The calculations were performed on clinical images and simulated images from anthropomorphic software breast phantoms. Our results show that β highly depends on the reconstruction algorithm. Differences in β values can be as high as 1.3 for a same case. In contrast to what has been previously published, it was found that β values calculated in DBT slices can be larger than β values calculated in projection images and this depends on the reconstruction algorithm.

9412-117, Session PSMon

Intrinsic noise power spectrum for the electronic noise in radiography image detectors

Dong Sik Kim, Hankuk Univ. of Foreign Studies (Korea, Republic of); Eun Kim, Choulwoo Shin, DRTECH Corp. (Korea, Republic of)

In order to design low-dose imaging systems, the radiography detector should have a good noise performance especially at low incident exposures. The signal-to-noise ratio (SNR) performance at low incident exposures is influenced by the electronic noise of readout circuits as well as the quantum noise of x-rays. Hence, analyzing the electronic noise of a detector is of importance in developing good detectors. However, the SNR value for electronic noise is zero and does not provide any useful information. Observing the standard deviation of the acquired image without exposure may confuse the analysis due to the inconsistent electronic gains of the readout circuits.

Hence, it is required to find an appropriate evaluation scheme for the electronic noise.

A blind electronic noise evaluation approach, which uses a set of acquired images at various incident exposures, is considered in this paper. We calculate the electronic gain and then derive an intrinsic noise power spectrum (NPS), which is independent of the electronic gain.

Furthermore, we can obtain the intrinsic NPS only for the electronic noise. The proposed evaluation schemes are experimentally tested for digital x-ray images, which are obtained from various development prototypes of direct and indirect detectors. It is shown that the proposed schemes can efficiently provide an evaluation of the electronic noise performance.

9412-118, Session PSMon

Noise performance studies of model-based iterative reconstruction (MBIR) as a function of kV, mA and exposure level: Impact on radiation dose reduction and image quality

Daniel Gomez-Cardona, Ke Li, Meghan G. Lubner, Perry J. Pickhardt, Guang-Hong Chen, Univ. of Wisconsin-Madison (United States)

The significance of understanding the noise properties of clinical CT systems is twofold: First, as the diagnostic performance (particularly for the detection of low contrast lesions) is strongly limited by noise, a thorough study of the dependence of image noise on scanning and reconstruction parameters would enable the desired image quality to be achieved with the least amount of radiation dose; Second, a clear understanding of the noise properties of CT systems allows one to identify the advantages and weaknesses in the hardware and data processing methods, which may help further improve the CT system's design or even motivate new CT technologies. In this work, a systematic study of the noise performance has been performed for a commercially available model-based iterative reconstruction (MBIR) method. The local noise power spectrum (NPS) was measured from repeated scans as a function of kV, mA and dose level. An adult-sized anthropomorphic abdomen phantom was used to target the study directly to specific clinical imaging task. Several novel findings have been disclosed in this work: On one hand, the classical linearity of CT noise has been violated in MBIR, as the shape of its NPS is no longer independent of dose level and noise variance is no longer linearly proportional to the inverse of dose; on the other hand, as long as the dose is fixed, both the shape and magnitude of the NPS for MBIR remain nearly invariant, whereas in FBP the noise magnitude increases at lower kV due to decreased x-ray transmission. These novel noise properties provides new opportunities for dose reduction and image quality improvement. For example, lower kV CT

scans for adult patients that were previous restricted due to dramatically increased noise may be enabled by MBIR.

9412-119, Session PSMon

Directional MTF measurement using sphere phantoms for a digital breast tomosynthesis system

Changwoo Lee, Jongduk Baek, Yonsei Univ. (Korea, Republic of)

The digital breast tomosynthesis (DBT) has been widely used as a diagnosis imaging modality of breast cancer because of potential for structure noise reduction, better detectability, and less breast compression. Since 3D modulation transfer function (MTF) is one of the quantitative metrics to assess the spatial resolution of medical imaging systems, it is very important to measure 3D MTF of the DBT system to evaluate the resolution performance. In order to do that, Samei et al. used sphere phantoms and applied Thornton's method to the DBT system. However, due to the limitation of Thornton's method, the low frequency drop, caused by the limited data acquisition angle and reconstruction filter, was not measured correctly. To overcome this limitation, we propose a Richardson-Lucy (RL) deconvolution based estimation method to measure the directional MTF. We reconstructed point and sphere objects using FDK algorithm within a 40° data acquisition angle. The ideal 3D MTF is obtained by taking Fourier transform of the reconstructed point object, and three directions (i.e., fx-direction, fy-direction, and f45°-direction) of the ideal 3D MTF are used as a reference. To estimate the directional MTF, the plane integrals of the reconstructed and ideal sphere object were calculated and used to estimate the directional PSF using RL deconvolution technique. Finally, the directional MTF was calculated by taking Fourier transform of the estimated PSF. Compared to the previous method, the proposed method showed a good agreement with the ideal directional MTF, especially at low frequency regions.

9412-120, Session PSMon

Comparison of methods for quantitative evaluation of endoscopic distortion

Quanzeng Wang, U.S. Food and Drug Administration (United States); Viraj N. Desai, U.S. Food and Drug Administration (United States) and Univ. of Maryland, Baltimore (United States); Kurt Castro, U.S. Food and Drug Administration (United States) and George Washington Univ. (United States); Wei-Chung Cheng, T. Joshua Pfefer, U.S. Food and Drug Administration (United States)

Endoscopy is a well-established paradigm in medical imaging, and emerging endoscopic technologies such as high resolution, capsule and disposable endoscopes promise significant improvements in effectiveness, as well as patient safety and acceptance of endoscopy. However, the field lacks practical standardized test methods to evaluate key optical performance characteristics (OPCs), in particular the geometric distortion caused by fisheye lens effects in clinical endoscopic systems. As a result, it has been difficult to compare an endoscope's image quality or assess its changes over time. The goal of this work was to identify optimal techniques for objective, quantitative characterization of distortion that are effective and not burdensome. Specifically, we compared distortion measurements from a commercially available distortion evaluation/correction software package with a custom algorithm based on a local magnification (ML) approach. Measurements were performed using both a clinical gastroscope and a capsule endoscope to image square grid targets. Recorded images were analyzed with the ML approach and the commercial software where the results were used to obtain corrected images. Corrected images based on the ML approach and the software were compared qualitatively by visualization and quantitatively by comparing them with undistorted

images. The effects of target grid size and distance were evaluated as well. The study showed that the ML method can assess distortion patterns more accurately than the commercial software. Overall, the development of standardized test methods for characterizing distortion and other OPCs will facilitate development, clinical translation, manufacturing quality and assurance of performance during clinical use of endoscopic technologies.

9412-121, Session PSMon

An experimental study of the accuracy in measurement of modulation transfer function using an edge method

Dong-Hoon Lee, Ye-Seul Kim, Hye-Suk Park, Young-Jin Lee, Hee-Joung Kim, Yonsei Univ. (Korea, Republic of)

Image evaluation is very important in digital radiography (DR) which is widely used in medical imaging. Among parameters of image evaluation, modulation transfer function (MTF) is the important factor in the field of medical imaging and necessary to obtain detective quantum efficiency (DQE) which represents overall performance of the detector signal-to-noise ratio. However, the accurate measurement of MTF is still not easy because of geometric effect, electric noise, quantum noise, and truncation error. Therefore, in order to improve accuracy of MTF, four experimental methods were tested in this study such as changing the tube current, applying smoothing method in edge spread function (ESF), adjusting line spread function (LSF) range, and changing tube angle. Our results showed that MTF's fluctuation was decreased by high tube current and smoothing method. However, tube current should not exceed detector saturation and smoothing in ESF generates distortion in ESF and MTF. In addition, decreasing LSF range diminished fluctuation and the number of sampling in MTF and high tube angle generates degradation in MTF. Based on these results, accurate MTF can be obtained at as high tube current as possible before detector saturation and the smoothing method should be avoided. Also, optimal range of LSF which consider reduction of fluctuation and the number of sampling in MTF was necessary and precise tube angle is essential to obtain accurate MTF. In conclusion, our results demonstrated that we can acquire accurate MTF. Furthermore, these results expected to be applied to the image evaluation of the digital tomosynthesis (DTS) system.

9412-122, Session PSMon

Physical performance testing of digital breast tomosynthesis

Takao Kuwabara, Kenji Yoshikawa, FUJIFILM Corp. (Japan)

Digital breast tomosynthesis has become accepted in clinical use. It is important to physically evaluate a system to ensure that it is working at full performance. Non-linear reconstruction processing is proposed to improve interpretation of clinical images by enhancing the minute contrasts of breast tissue while suppressing metal artifacts. Because existing measuring methods assume system linearity, physical evaluation applied to images reconstructed with non-linear processing may result in unnatural values.

We evaluated physical performance using images reconstructed by the following methods:

(1) Non-linear: the processing used in Aspire Cristalle (FDR AMULET Innovality outside the United States; Fujifilm). Non-linear processing with the suppression metal artifacts and enhancement of minute tissue contrast is adopted.

(2) Simple: Back projection processing without filter processing.

(3) Shepp-Logan: Filtered back projection processing using Shepp-Logan type filter.

The physical evaluation was executed in accordance with EUREF "Protocol for the Quality Control of the Physical and Technical Aspects of Digital Breast Tomosynthesis Systems Draft version 0.15".

It is important to measure and record device performance to ensure the

stability of a device from the installation and it is desirable to eliminate the influence of changes in reconstruction processing. Continuous improvements of reconstruction processing are undertaken to improve clinical image quality. Physical performance values are greatly influenced by the type of reconstruction processing. Simple back projection is the optimum type of processing to confirm device performance as it directly reflects the device performance. Therefore, use of images reconstructed by simple back projection is recommended.

9412-123, Session PSMon

Iterative CT reconstruction with small pixel size: distance-driven forward projector versus Joseph's

Katharina Hahn, Utah Ctr. for Advanced Imaging Research (United States) and Friedrich-Alexander-Univ. Erlangen-Nürnberg (Germany) and Siemens AG, Healthcare Sector (Germany); Ulrich Rassner, Chris Davidson, The Univ. of Utah (United States); Harald Schöndube, Karl Stierstorfer, Siemens AG (Germany); Joachim Hornegger, Friedrich-Alexander-Univ. Erlangen-Nürnberg (Germany); Frédéric Noo, The Univ. of Utah (United States)

Over the last few years, iterative reconstruction methods have become an important research topic in x-ray CT imaging. This effort is motivated by increasing evidence that such methods may enable significant savings in terms of dose imparted to the patient. Conceptually, iterative reconstruction methods involve two important ingredients: the statistical model, which includes the forward projector, and a priori information in the image domain, which is expressed using a regularizer. Most often, the image pixel size is chosen to be equal (or close) to the detector pixel size (at field-of-view center). However, there are applications for which a smaller pixel size is desired. In this investigation, we focus on reconstruction with a pixel size that is twice smaller than the detector pixel size. Using such a small pixel size implies a large increase in computational effort when using the distance-driven method for forward projection, which models the detector size. On the other hand, the more efficient method of Joseph will create imbalances in the reconstruction of each pixel, in the sense that there will be large differences in the way each projection contributes to the pixels. The purpose of this work is to evaluate the impact of these imbalances on image quality in comparison with utilization of the distance-driven method. The evaluation involves computational effort, bias and noise metrics, and LROC analysis using human observers. The results show that Joseph's method largely remains attractive.

9412-124, Session PSMon

Application of the fractal Perlin noise algorithm for the generation of simulated breast tissue

Magnus Dustler, Lund Univ. (Sweden); Predrag R. Bakic, Univ. of Pennsylvania (United States); Hannie Petersson, Pontus A. Timberg, Anders Tingberg, Sophia Zackrisson, Lund Univ. (Sweden)

Software breast phantoms are increasingly seeing use in preclinical validation of breast image acquisition systems and image analysis methods. Phantom realism has been proven sufficient for numerous specific validation tasks. A challenge is the generation of suitably realistic small-scale breast structures that could further improve the quality of phantom images. Power law noise follows the noise power characteristics of breast tissue, but may not sufficiently represent certain (e.g., non-Gaussian) properties seen in clinical breast images. The purpose of this work was to investigate the utility of fractal Perlin noise in generating more realistic breast tissue through

investigation of its power spectrum and visual characteristics.

Perlin noise is an algorithm that creates smoothly varying random structures of an arbitrary frequency. Through the use of a technique known as fractal noise or fractional Brownian motion (fBm), octaves of noise with different frequency are combined to generate coherent noise with a broad frequency range. FBm is controlled by two parameters - lacunarity and persistence - related to the frequency and amplitude of successive octaves, respectively. Average noise power spectra were calculated and beta parameters estimated in sample volumes of fractal Perlin noise with different combinations of lacunarity and persistence.

Certain combinations of parameters resulted in noise volumes with beta values between 2 and 3, corresponding to measurements in real breast tissue. Different combinations of parameters resulted in different visual appearances. Quantitative and qualitative analysis of the generated patterns is ongoing. In conclusion, Perlin noise offers a flexible tool for generating breast tissue with realistic properties.

9412-125, Session PSMon

Investigating materials for breast nodules simulation by using segmentation and similarity analysis of digital images

Paula N. Siqueira, Karem D. Marcomini, Homero Schiabel, Univ. de São Paulo (Brazil); Homero Schiabel, University of São Paulo (Brazil) and Univ. de São Paulo (Brazil)

The task of identifying the malignancy of nodular lesions on mammograms becomes quite complex due to overlapped structures or even to the granular fibrous tissue which can cause confusion in classifying masses shape, leading to unnecessary biopsies. Efforts to develop methods for automatic masses detection in CADe (Computer Aided Detection) schemes have been made with the aim of assisting radiologists and working as a second opinion. The validation of these methods may be accomplished for instance by using databases with clinical images or acquired through breast phantoms. Hence these phantom images should represent as close as possible the actual lesions in order to provide a more reliable evaluation of such methods. With this aim, some types of materials were tested in order to produce radiographic phantom images which could characterize a good enough approach to the typical mammograms corresponding to actual breast nodules. Therefore different nodules patterns were physically produced and used on a previous developed breast phantom. Their characteristics were tested according to the digital images obtained from phantom exposures at a LORAD M-IV mammography unit. Regions of interest containing the simulated nodules were segmented as by an automated segmentation scheme as well as by an experienced radiologist who has delineated the contour of each nodule by means of a graphic display digitizer. Both results were compared by using evaluation metrics. Although all the tested materials proved to be suitable for the study of nodules in phantom images, the PVC sheet yielded the best results.

9412-126, Session PSMon

Acoustic characterization of polyvinyl chloride and self-healing silicone as phantom materials

Dennis A. Ceh, Univ. of Windsor (Canada); Terry M. Peters, Elvis C. S. Chen, Robarts Research Institute (Canada)

Phantoms are physical constructs used in procedure planning, training, medical imaging research and with machine calibration. Depending on the application, the material a phantom is made out of is very important. With ultrasound imaging, the tissue mimicking materials used need to have similar acoustic properties as tissue (namely speed of sound and attenuation). Phantoms used with needle insertion require a material with a similar tensile strength as tissue and if possible a self healing ability to

increase its overall lifespan. Here, soft polyvinyl chloride (PVC) and silicone compounds were tested as possible needle insertion phantom materials. Tests were done by using a time of flight technique, where a pulse was passed through a sample contained in a water bath. The speed of sound and attenuation were both determined manually and through spectral analysis. With PVC it was determined to have a speed of sound of approximately 1395 m/s and attenuation of 0.441 dB/cm (at 1 MHz).

For the silicone mixture, the respective speed of sound and attenuation values were tdb m/s and tdb dB/cm (at 1 MHz).

9412-127, Session PSMon

SPECT reconstruction using DCT-induced tight framelet regularization

Jiahan Zhang, Syracuse Univ. (United States); Si Li, Yuesheng Xu, Sun Yat-Sen Univ. (China); C. Ross Schmidtlein, Memorial Sloan-Kettering Cancer Ctr. (United States); Edward D. Lipson, Syracuse Univ. (United States); David H. Feiglin, Andrzej Krol, SUNY Upstate Medical Univ. (United States)

Wavelet transforms has been successfully applied to many fields of image processing. Yet, to our knowledge, it has never been directly incorporated in the objective function in Emission Computed Tomography (ECT) image reconstruction before. Our aim was to investigate if the l1-norm of discrete cosine transform (DCT) wavelet frame transform of the estimated radiotracer distribution could be effectively used as the regularization term in the penalized-likelihood (PL) reconstruction, where a regularizer is used to enforce the smoothness of reconstructed images.

In our initial studies, l1-norm of 2D DCT wavelet decompositions was used as a regularization term. Our preconditioned alternating projection algorithm (PAPA), proposed in earlier work to solve PL reconstruction with non-differentiable regularizers, was used to solve the optimization problem. The DCT wavelet decompositions were performed on the transaxial reconstructed images and the auxiliary vector b. We reconstructed Monte Carlo simulated SPECT data obtained for a phantom with Gaussian blobs as hot lesions and with warm random lumpy background. Reconstructed images using the proposed method exhibited better noise suppression and improved lesion conspicuity, as compared with images reconstructed using expectation maximization (EM) algorithm with Gaussian post filter (GPF). Also the mean square error (MSE) was smaller, as compared with EM-GPF. A critical and difficult aspect this method is selection of optimal parameters.

In summary, our numerical experiments demonstrated that the l1-norm of discrete cosine transform (DCT) wavelet frame transform DCT regularizer shows promise for SPECT image reconstruction using PAPA method.

9412-128, Session PSMon

Robust iterative image reconstruction for breast CT by use of projection differentiation

David N. Kraemer, Grinnell College (United States); Erin G. Roth, Carleton College (United States); Emil Y. Sidky, Ingrid S. Reiser, Xiaochuan Pan, The Univ. of Chicago Medical Ctr. (United States)

Design of image reconstruction algorithms for breast CT faces challenging conditions: projection data are often truncated particularly near the chest wall, and the noise level in the acquired projections is high when constraining the scan to have equivalent dose as two-view mammography. Recently, we have been investigating a design of iterative image reconstruction algorithms that employ a differentiation filter on the projection data and estimated projections. The extra processing step can potentially reduce the impact of artifacts due to projection truncation in addition to enhancing edges in the reconstructed volumes. The edge

enhancement can improve visibility of various tissue structures. Previously, this idea has been incorporated in an approximate solver of the associated optimization problem. In the present work, we present reconstructed volumes with clinical breast CT data, which result from accurate solution of this optmization problem. Furthermore, we employ singular value decomposition (SVD) to help determine filter parameters and to interpret the properties of the reconstructed volumes.

9412-129, Session PSMon

Adapted fan-beam volume reconstruction for stationary digital breast tomosynthesis

Gongting Wu, Christine R. Inscoe, The Univ. of North Carolina at Chapel Hill (United States); Jabari Calliste, Yueh Z Lee, Univ of North Carolina at Chapel Hill (United States); Otto Zhou, Jianping Lu, The Univ. of North Carolina at Chapel Hill (United States)

Digital breast tomosynthesis (DBT) provides 3D images which removes tissue overlapping and enables better cancer detection. Stationary DBT (s-DBT) uses a fixed X-ray source array to eliminate image blur associated with the x-ray tube motion and provides better image quality as well as faster scanning time. For limited angle tomography, it is known that iterative reconstructions generally produces better image with less artifacts. However classical iterative tomosynthesis reconstruction methods sample the reconstruction space as one single 3-D matrix, which consumes large memory and computing power, and they are considerably slower than the filtered backward projection (FBP) reconstruction. The linear x-ray source array used in s-DBT enables a computationally more efficient volume reconstruction using adapted fan beam sampling, which simplifies the 3-D cone beam reconstruction to a series of 2-D fan beam reconstructions. In this paper, we report the first results of the adapted fan-beam volume reconstruction (AFVR) for the s-DBT system currently undergoing clinical trial at UNC, using a simultaneous algebraic reconstruction technique (SART). An analytic breast phantom is used to quantitatively analyze the performance of the AFVR. Image qualities of a CIRS breast phantom reconstructed using the AFVR method are compared to that using FBP technique with a commercial package. Our results show image reconstructed by SART with AFVR method had a better sharpness compared to that using FBP. By utilizing parallel computing with GPU, it is expected that the AFVR method will enable iterative reconstruction technique to be practical for clinical applications.

9412-130, Session PSMon

Adaptive nonlocal means-based regularization for statistical image reconstruction of low-dose X-ray CT

Hao Zhang, Jianhua Ma, Stony Brook Univ. (United States); Jing Wang, The Univ. of Texas Southwestern Medical Ctr. at Dallas (United States); Yan Liu, Hao Han, Stony Brook Univ. (United States); Lihong Li, College of Staten Island-CUNY (United States); Zhengrong Liang, Stony Brook Univ. (United States)

To reduce radiation dose in X-ray computed tomography (CT) imaging, one common strategy is to lower the energy settings of X-ray tube (mA, kV) during projection data acquisition. However, this strategy would inevitably increase the projection data noise, and the resulting image by the filtered back-projection (FBP) method may suffer from excessive noise and streak artifacts. The edge-preserving nonlocal means (NLM) filtering can help reduce the noise-induced artifacts in the FBP reconstructed image, but it sometimes cannot completely eliminate them, especially under very low-dose circumstance when the image is severely degraded. To deal with this situation, we proposed a penalized weighted least-squares (PWLS)

image reconstruction scheme using NLM-based regularization, which can effectively suppress the noise-induced artifacts. However, we noticed that using uniform filtering parameter in the NLM-based regularization was rarely optimal for the whole image. Therefore, we further developed novel adaptive filtering parameters by considering local characteristics of the image, and the resulting method is referred to as adaptive NLM-regularized PWLS image reconstruction. Experimental results with physical phantom and clinical patient data validated the superiority of using the proposed adaptive NLM regularization for low-dose CT reconstruction, in terms of noise/streak artifacts suppression and edge/detail/contrast/texture preservation.

9412-131, Session PSMon

Performance evaluation of a novel high performance pinhole array detector module using NEMA NU-4 image quality phantom for four head SPECT Imaging

Tasneem Rahman, Murat Tahtali, Mark R. Pickering, UNSW Canberra (Australia)

Radiolabeled tracer distribution imaging of gamma rays using pinhole collimation is considered promising for small animal imaging. The recent availability of various radiolabeled tracers has enhanced the field of diagnostic study and is simultaneously creating demand for high resolution imaging devices. This paper presents analyses to represent the optimized parameters of a high performance pinhole array detector module using two different characteristics phantoms. Monte Carlo simulations using the Geant4 application for tomographic emission (GATE) were executed to assess the performance of a four head SPECT system incorporated with pinhole array collimators. The system is based on a pixelated array of NaI(Tl) crystals coupled to an array of position sensitive photomultiplier tubes (PSPMTs). The detector module was simulated to have 48 mm by 48 mm active area along with different pinhole apertures on a tungsten plate. The performance of this system has been evaluated using a uniform shape cylindrical water phantom along with NEMA NU-4 image quality (IQ) phantom filled with Tc-99m labeled radiotracers. SPECT images were reconstructed where activity distribution is expected to be well visualized. This system offers the combination of an excellent intrinsic spatial resolution, good sensitivity and signal-to-noise ratio along with high detection efficiency over an energy range between 20-160 keV. Increasing number of heads in a stationary system configuration offers increased sensitivity at a spatial resolution similar to that obtained with the current SPECT system design with four heads.

9412-132, Session PSMon

A mathematical approach to image reconstruction in dual-energy computed tomography

Kiwan Jeon, National Institute for Mathematical Sciences (Korea, Republic of); Sungwhan Kim, Hanbat National Univ. (Korea, Republic of); Chi Young Ahn, Sung-Ho Kang, Taeyoung Ha, National Institute for Mathematical Sciences (Korea, Republic of)

In this paper, we provide a mathematical approach to reconstruct the Compton scatter and photo-electronic coefficient using the dual-energy CT (DECT) system. The proposed imaging method is based on the mean value theorem to handle the non-linear integration coming from the polychromatic energy based CT scan system. It gives a new reconstruction algorithm without additional calibration in DECT. We show a numerical simulation result for the validation of the proposed algorithm.

9412-133, Session PSMon

Statistical model based iterative reconstruction in time-resolved CT imaging: exploitation of the low dimensionality of the spatial-temporal image matrix

Yinsheng Li, Kai Niu, Guang-Hong Chen, Univ. of Wisconsin-Madison (United States)

Time-resolved CT imaging methods play an increasing important role in clinical practice, particularly, in the diagnosis and image-guided intervention of vascular disease. In a time-resolved CT imaging protocol, it is often necessary to expose the patients x-ray radiation for an extended period of time, and as a result the cumulative radiation dose in these CT applications is often higher than that of static CT imaging protocols. This high cumulative dose means it is important to develop new means of reducing radiation dose for time-resolved CT imaging. In this paper, we present a novel statistical model based iterative reconstruction method that enables the reconstruction of low noise time-resolved CT images at low radiation exposure levels. To achieve this purpose, the statistical model based iterative reconstruction in time-resolved CT imaging framework was proposed in this study. Unlike other well known statistical reconstruction methods, this new method primarily exploits the intrinsic low dimensionality of time-resolved CT images to regularize the reconstruction. The minimization of the single cost function was neatly decoupled into a data consistency problem and an image weighted denoising problem. Both of them can be solved in a manner with both high convergence rate and high parallelizability. IRB approved human perfusion exam was used to evaluate the framework qualitatively and quantitatively.

9412-134, Session PSMon

Statistical iterative reconstruction for multi-contrast x-ray micro-tomography

Sebastian Allner, Astrid Velroyen, Andreas Fehringer, Franz Pfeiffer, Peter B. Noël, Technische Univ. München (Germany)

In the past decade the application of iterative reconstruction became feasible in a daily manner due to increasing computation power. However, in micro-tomography those algorithms only find slowly the way into the daily routine. The reconstruction of tomographic data is normally done with an analytical algorithm, such as a filtered back-projection, which provides suboptimal image quality when confronted with noisy or undersampled data. For micro-tomography and phase-contrast micro-tomography high resolution and image quality are the most important performance measures. These prerequisites lead to very long exposure times due to small detector pixel sizes in combination with limited flux of conventional x-ray sources. To show the broad range of cost-function-based iterative reconstruction for micro x-ray systems, we acquired phase-contrast micro-tomography data. We chose data from a grating-based phase-contrast setup, because multiple intensities of an interference pattern have to be taken per projection to retrieve the complementary information of the conventional absorption, differential phase and scattering signals. This methodical prerequisite increases drastically the scan time per single projection, which makes the need for shorter scanning schemes, e.g. undersampling, even more compelling. The performance with respect to image quality and resolution of SIR reconstructed images is qualitatively and quantitatively assessed. The results from the assessment illustrate that SIR offers not only significantly higher image quality, but also enables high-resolution imaging from highly undersampled data in comparison to an FBP algorithm.

9412-136, Session PSMon

Multi-dimensional tensor-based adaptive filter (TBAF) for low dose x-ray CT

Michael Knaup, Deutsches Krebsforschungszentrum (Germany); Sergej Lebedev, Stefan Sawall, German Cancer Research Center (DKFZ) (Germany); Marc Kachelriess, Deutsches Krebsforschungszentrum (Germany)

Edge-preserving adaptive filtering within CT image reconstruction is a powerful method to reduce image noise and hence to reduce patient dose. However, highly sophisticated adaptive filters typically comprise many parameters which must be adjusted carefully in order to obtain optimal filter performance and to avoid artifacts caused by the filter. In this work we applied an anisotropic tensor-based adaptive image filter (TBAF) to CT image reconstruction, both as an image-based post-processing step, as well as a regularization step within an iterative reconstruction. The TBAF is a generalization of the filter of reference [H. Knutsson, "Representing Local Structure Using Tensors", the 6th Scandinavian Conference on Image Analysis, Oulu, Finland, pp. 244-251, June 1989]. Provided that the image noise (i.e. the variance) of the original image is known for each voxel, we adjust all filter parameters automatically. Hence, the TBAF can be applied to any individual CT dataset without user interaction. This is a crucial feature for a possible application in clinical routine. The TBAF is compared to a well-established adaptive bilateral filter using the same noise adjustment. Although the differences between both filters are subtle, edges and local structures emerge more clearly in the TBAF filtered images while anatomical details are less affected than by the bilateral filter.

9412-137, Session PSMon

Impact of covariance modeling in dual-energy spectral CT image reconstruction

Yan Liu, Stony Brook Univ. (United States); Zhou Yu, Yu Zou, Toshiba Medical Research Institute USA (United States)

Dual-energy computed tomography (DECT) is a recent advancement in CT technology, which can reduce beam hardening artifacts and provide material composition information compared to conventional CT. Recently, statistical iterative reconstruction (SIR) methods were introduced to DECT image reconstruction for radiation dose reduction. The statistical noise modeling of measurements plays an important role in conventional CT SIR and impacts on the image quality. In DECT, the measurements are often decomposed to basis material sinograms. Unlike the conventional CT sinogram data, the decomposed basis material sinograms have strong correlations. Although an accurate DECT noise modeling contains correlations is expected to benefit the image quality in SIR, the amount of improvement is unknown and difficult to study. Directly utilizing the accurate noise model in some numerical methods is challenging due to the non-diagonal properties. In this study, we evaluate the performances of the two noise models (i.e., accurate noise model and simplified model by ignoring correlations) in numerical methods and then assess the corresponding image quality by analyzing the bias and variance tradeoff. The results indicate that using the non-diagonal covariance matrix in SIR is challenging; some numerical methods may spend extreme long time to converge. The bias-variance curve shows that in the same bias level, the accurate noise modeling has up to 20% noise reduction compared to the simplified model. Due to this significant improvement, the correlations between two decomposed sinograms should not be neglected. An efficient numerical algorithm with the consideration of accurate noise model is necessary for DECT image reconstruction.

9412-138, Session PSMon

Direct composite fillings: an optical coherence tomography And microCT investigation

Meda-Lavinia L. Negrutiu, Cosmin Sinescu, Mugurel V. Borlea, Univ. of Medicine and Pharmacy Victor Babes Timisoara (Romania); Adrian Manescu, Univ. Politecnica delle Marche (Italy); Virgil-Florin Duma, Aurel Vlaicu Univ. of Arad (Romania); Mihai Rominu, Univ. of Medicine and Pharmacy Victor Babes Timisoara (Romania); Adrian G. Podoleanu, Univ. of Kent (United Kingdom)

The treatment of carious lesions requires removal of affected dental tissue thus creating cavities that are to be filled with dedicated materials.

There are several methods known which are used to assess the quality of direct dental restorations, but most of them are invasive. Optical tomographic techniques are of particular importance in the medical imaging field, because these techniques can provide non-invasive diagnostic images. Using an en-face version of OCT, we have recently demonstrated real time thorough evaluation of quality of dental fillings.

The major aim of this study was to analyses the optical performance of adhesives modified with zirconia particles in different concentrations in order to improve the contrast of OCT imaging of the interface between the tooth structure, adhesive and composite resin. The OCT investigations were validated by micro CT using synchrotron radiation.

The OCT Swept Source is a valuable investigation tool for the clinical evaluation of class II direct composite restorations. The unmodified adhesive layer shows poor contrast on regular OCT investigations. Adding zirconia particles to the adhesive layer provides a better scattering which allows a better characterization and quantification of direct restorations.

9412-139, Session PSMon

A clinical evaluation of total variation-stokes image reconstruction strategy for low-dose CT imaging of the chest

Yan Liu, Hao Zhang, Stony Brook Univ. (United States); William Moore, Stony Brook Medicine (United States); Priya Bhattacharji, Zhengrong Liang, Stony Brook Univ. (United States)

Twenty-five "normal-dose" computed tomography (CT) studies of the chest (i.e., 1,160 projection views, 120kVp, 100mAs) data sets were acquired from the patients who were scheduled for lung biopsy at Stony Brook University Hospital under informed consent approved by our Institutional Review Board. In this study, sparse projection views were evenly extracted from the total 1,160 projections of each patient to mimic low-dose CT imaging scenario (i.e., sparse-view scan) and the total radiation dose was reduced according to how many sparse views were selected. A standard filtered back-projection (FBP) algorithm was applied to the 1160 projections to produce reference images for comparison purpose. In the low-dose scenario, both the FBP and total variation-stokes (TVS) algorithms were applied to reconstruct the corresponding low-dose images. The reconstructed images were evaluated by an experienced thoracic radiologist against the reference image. Both the low-dose reconstructions and the reference images were displayed on a 2.5-megapixel monitor in soft tissue and lung windows. The images were graded by using a five-point scale from 0 to 4 (0, non-diagnostic; 1, severe artifact with low confidence; 2, moderate artifact or moderate diagnostic confidences; 3, mild artifact or high confidence; 4, well depicted without artifacts). More quantitative evaluation measurements such as standard deviations for different tissue types and universal quality index were also studied and reported for the TVS results. The evaluation concluded that the TVS can reduce the view number from 1,160 to 386 with slightly lower scores as the reference, resulting in a dose reduction to close 33%.

9412-140, Session PSMon

CBCT reconstruction via a penalty combining total variation and its higher-degree term

Nanbo Sun, Tao Sun, Huazhong Univ. of Science and Technology (China); Jing Wang, The Univ. of Texas Southwestern Medical Ctr. at Dallas (United States); Shan Tan, Huazhong Univ. of Science and Technology (China)

The high radiation exposure to normal tissue during acquisition of the cone-beam CT (CBCT) projection data will significantly increase the risk of cancer and genetic defects. In order to reduce the radiation dose, the main method is to reduce the mAs of the scans, which will lead to a degraded CBCT images. One of statistical iterative reconstruction (SIR) algorithms, the penalized weighted least-squares (PWLS) iterative algorithm with a total variation penalty (PWLS-TV), has shown potential to improve CBCT image quality, suppressing noise and preserving edge. However, the PWLS-TV algorithm often leads to the annoying staircase effect. In this study, we proposed to use a new penalty, namely TV-H penalty, which combines the TV penalty and Hessian based norm penalty for CBCT reconstruction. The TV-H penalty retains some of the most favorable properties of the TV penalty like suppressing noise and preserving the edge and has a better ability in preserving the structure of gradual transition in images, providing a potential advantage in suppressing the staircase effect of the TV penalty. An effective algorithm was developed to minimize the objective function based on the penalized weighted least-squares (PWLS) criterion with the majorization-minimization (MM) approach. Two simulated digital phantoms and one physical phantoms were used to compare the performance of TV, Hessian based norm penalty and TV-H penalty, which shows that the TV-H penalty outperforms the TV and Hessian based norm penalty.

9412-142, Session PSMon

Limited angle C-arm tomosynthesis reconstruction algorithms

Nuhad A. Malalla, Ying Chen, Shiyu Xu, Southern Illinois Univ. Carbondale (United States)

In this paper, tomosynthesis based on c-arm with digital detector is investigated as a novel three dimensional (3D) imaging technique. Digital tomosythses is an imaging technique to provide 3D information of the object by reconstructing slices through the object from a series of angular projection views with respect to the object. C-arm tomosynthesis provides two dimensional (2D) x-ray projection images with a single rotation (±20 angular range) of both x-ray source and detector. In this paper, four representative reconstruction algorithms including point by point back projection (BP), filtered back projection (FBP), simultaneous algebraic reconstruction technique (SART) and Maximum Likelihood expectation maximization (MLEM) were investigated. Dataset of 25 projection views of 3D spherical object that located at center of c-arm was simulated from 25 angular locations over a total view angle 40 degrees. With reconstructed images, 3D mesh plot and 2D line profile of normalized pixel intensities on focus reconstruction plane crossing the center of the object showed the ability of each reconstruction method to generate reconstruction images. Overall the results demonstrated the ability to generate 3D information from limited angle c-arm tomosynthesis. Since c-arm tomosynthesis is compact, portable and can avoid the patient moving, it has been developed for different clinical application ranging from tumor surgery to interventional radiology. It is very important to evaluate C-arm tomosynthesis for valuable applications.

9412-143, Session PSMon

Hessian Schatten-norm regularization for CBCT image reconstruction using fast iterative shrinkage-thresholding algorithm

Xinxin Li, Huazhong Univ. of Science and Technology (China); Jiang Wang, The Univ. of Texas Southwestern Medical Ctr. at Dallas (United States); Shan Tan, Huazhong Univ. of Science and Technology (China)

Cone-beam computed tomography (CBCT) has become an increasingly widely used technique in radiation therapy. To find precise position of lesions during medical treatment, it is important to get as accurate reconstructed images as possible. Statistical iterative reconstruction with total variation (TV) has shown potential to improve image quality, especially in suppressing noises and preserving edges. However, it often leads to the well-known staircase-effect. In this study, we introduced a new penalty using Hessian Schatten-norm for CBCT reconstruction that achieves better performance than the TV penalty. The new penalty maintains most of the favorable properties of the TV penalty. Moreover, it can overcome the staircase effect observed in TV-based CBCT reconstruction. The main reason is that higher-order derivatives in the Hessian Schatten-norm can potentially avoid the over-sharpening of regions with smooth intensity transitions. We adopted a fast iterative shrinkage thresholding algorithm (FISTA) to speed up the converging of the algorithm. Experiments on one digital phantom and one physical phantom demonstrated that the reconstruction method using Hessian schatten norm as regularization term outperforms TV-based reconstruction method, particularly in avoiding the over-sharpening of the smooth intensity transitions in the reconstructed image.

9412-144, Session PSMon

Extension of the Fourier slice theorem for evaluating the frequencies on the whole square domain for the inverse Fourier transform

Xiqiang Zheng, Voorhees College (United States)

For two dimensional X-ray computed tomography (CT) image reconstruction using direct Fourier transform methods, by Fourier slice theorem, the frequencies from the Radon transforms of the one dimensional projections are mapped to polar lines on a polar grid, and the frequencies on the polar grid occupy a circular region. To apply standard inverse fast Fourier transform algorithms to restore the image, the usual method is to interpolate the frequencies on the polar lines into a Cartesian grid and assume that the frequencies outside the circular region are zeros.

In this presentation, we show how to extend the Fourier slice theorem to evaluate the frequencies outside the circular region reasonably instead of the assumption of zeros. Some simulation results will be shown to compare our new method with the usual direct Fourier transform methods. Based on the usual image reconstruction quality criteria, we will show the effectiveness of our new method.

9412-145, Session PSMon

Absorption imaging performance of a grating based multi-contrast imaging system: magnitude and effects of x-ray scatter

Yongshuai Ge, John W. Garrett, Ke Li, Guang-Hong Chen, Univ. of Wisconsin-Madison (United States)

In this work, we performed both Monte Carlo simulations and experimental measurements to investigate the impact of x-ray scatter on the performance of absorption imaging in a Talbot-Lau interferometer based multicontrast imaging system. The preliminary experimental results show that the G2 grating used in our current benchtop system is able to reject Compton scatter signals and improve the scatter to primary ratio (SPR) by about 50%. Due to the SPR improvement, at a fixed dose the final contrast-to-noise ratio in the absorption image has been found to be comparable with and without the G1 and G2 gratings present in the imaging system.

9412-146, Session PSMon

Comparison of CT scatter rejection effectiveness using antiscatter grids and energy-discriminating detectors

Erica Cherry, Rebecca Fahrig, Stanford Univ. (United States)

A potential application for energy-discriminating detectors (EDD) is scatter rejection in CT. If paired with a monoenergetic source, EDDs can identify scattered photons by their reduced energy relative to primary photons. However, it is unknown how the scatter rejection of an EDD compares with that of an antiscatter grid.

In this study, the scatter rejection efficiency of energy-integrating detectors (EIDs) with antiscatter grids was compared with that of EDDs. Monte Carlo simulations were performed to generate projection images of head and body-sized cylindrical water phantoms in a typical clinical CT scanner geometry. Eight different detectors were used: four EIDs with 1D antiscatter grids of different heights (between 1 mm and 20 mm) and four EDDs with different energy bin sizes (between 0.1 keV and 10 keV.) Scatter to primary ratio (SPR) was calculated for each phantom/detector setup.

The results showed that most antiscatter grids/EID setups outperformed EDD setups. The EDD with the smallest energy bin size (0.1 keV) produced slightly better SPR than a 5-mm-tall antiscatter grid for both phantoms, but the more realistic 1 keV energy bin EDD outperformed only a 1-mm-tall grid. Clinical CT systems often include antiscatter grids taller than 5 mm, so the data suggest that EDDs would provide little advantage in SPR reduction unless an extremely small energy bin size was used. For a complete evaluation of EDD utility, however, additional factors, such as their larger active area and flexibility in different system geometries, must be considered.

9412-147, Session PSMon

Evaluation of the effective focal spot size of x-ray tubes by utilizing the edge respose analysis

Masayuki Nishiki, International Univ. of Health and Welfare (Japan)

Evaluation of the effective focal spot size of X-ray tube has been made utilizing the slit or the pin-hole camera, but is not widely used in a daily practice due to the need of specialized tools. The author proposes a simplified method in which only a metal edge and a digital detector are used, together with a process of removing detector blur inherently associated with the adoption of such a detector. The evaluation was made through the OTF (Optical Transfer Function) measurements by using the edge response analysis. Through the whole study, the use of OTF instead of MTF (Modulation Transfer Function) was essential in order to stay within the linear systems theory framework, at cost of handling complex functions. Evaluation steps were as follows; 1. The inherent OTF of the FPD (OTFdet) was measured by acquiring an image of the edge being closely contacted to the FPD. 2. The second OTF (OTFmulti) was measured with the edge placed apart from the FPD so as to implement 2 times geometrical magnification of the edge. OTFmulti is the product of OTFdet and the focal spot OTF (OTFfocus). 3. OTFfocus was obtained by calculating OTFmulti / OTFdet, thus removing the detector blur completely. 4. The LSF of the focal spot

was obtained through the inverse Fourier transformation of OTFfocus. The resultant LSFfocus was assured to be a real function due to the fact that original LSFdet and LSFmulti were both real functions. Preliminary results well matched those obtained by the pinhole camera.

9412-148, Session PSMon

Model based predictive design of post patient collimation for whole body CT scanners

Prakhar Prakash, John M. Boudry, GE Healthcare (United States)

Scatter presents as a significant source of image artifacts in cone beam CT (CBCT) and considerable effort has been devoted to measuring the magnitude and influence of scatter. Scatter management includes both rejection and correction approaches, with anti-scatter grids (ASGs) commonly employed as scatter rejection strategy.

This work employs a Geant4 driven Monte Carlo model to investigate the impact of different ASG designs on scatter rejection performance across a range of scanner coverage along the patient axis. Scatter rejection is quantified in terms of scatter to primary ratio (SPR). One-dimensional (1D) ASGs (grid septa running parallel to patient axis) are compared across a range of septa height, septa width and material.

Results indicate for a given septa width and patient coverage, SPR decreases with septa height but demonstrates diminishing returns for larger height values. For shorter septa heights, higher Z materials (e.g., Tungsten) exhibit superior scatter rejection to relatively lower Z materials (e.g., Molybdenum). For taller septa heights, the material difference is not as significant.

The results are intended to serve as guide for designing post patient collimation for whole body CT scanners. Since taller grids with high Z materials pose a significant manufacturing cost, it is necessary to evaluate optimal ASG design to minimize material and machining cost and meet scatter rejection specifications at given patient coverage.

9412-149, Session PSMon

Measurements and simulations of coherent scatter imaging as a simultaneous adjunct for screening mammography

Katie Kern, Univ. at Albany (United States); Laila Hassan, Lubna Peerzada, Univ. at Albany (United States); Mahboob Ur-Rehman, Univ at Albany, SUNY (United States); Carolyn A. MacDonald, Univ. at Albany (United States)

X-ray coherent scatter is dependent upon the molecular structure of the scattering material and hence allows differentiation between tissue types with potentially much higher contrast than conventional absorption-based radiography. Coherent-scatter computed tomography has been used to produce images based on the x-ray scattering properties of the tissue. However, the geometry for CT imaging requires a thin fan beam and multiple projections and is incommensurate with screening mammography.

In this work we demonstrate progress in a developing a system using a wide slot beam and simple anti-scatter grid which is adequate to differentiate between scatter peaks to remove the fat background from the coherent scatter image. Adequate intensity in the coherent scatter image can be achieved at the dose commonly used for screening mammography to detect carcinoma surrogates as small as 2 mm in diameter. This technique would provide an inexpensive, low dose, simultaneous adjunct to conventional screening mammography to provide a localized map of tissue type that could be overlaid on the conventional transmission mammogram. Comparisons between phantom measurements and Monte Carlo simulations show good agreement, which allowed for detailed examination of the visibility of carcinoma under realistic conditions.

9412-150, Session PSMon

Prospective gated chest tomosynthesis using CNT X-ray source array

Jing Shan, Laurel Burk, The Univ. of North Carolina at Chapel Hill (United States); Gongting Wu, Univ of North Carolina at Chapel Hill (United States); Yueh Z. Lee, The Univ. of North Carolina at Chapel Hill (United States); Michael D. Heath, Xiaohui Wang, David H. Foos, Carestream Health, Inc. (United States); Jianping Lu, Otto Zhou, The Univ. of North Carolina at Chapel Hill (United States)

Chest tomosynthesis is a low-dose 3-D imaging modality that has been shown to have comparable sensitivity as CT in detecting lung nodules, if the scan speed is sufficient high or there is not significant lung motion during imaging. We have recently demonstrated the feasibility of stationary chest tomosynthesis (s-DCT) using a distributed CNT X-ray source array. The technology allows acquisition of tomographic projections without moving the X-ray source, thus eliminates the focal spot blur. The electronically controlled CNT x-ray source also enables physiologically gated imaging, which will minimize image blur due to patient motion. In this paper, we investigate the feasibility of prospective gated chest tomosynthesis using a bench-top s-DCT system with a CNT source array, a high-speed flat panel detector and realistic patient respiratory signals captured using a pressure sensor. Tomosynthesis images of inflated pig lungs placed inside an anthropomorphic chest phantom were acquired at different respiration rate, with and without gating for image quality comparison. Metal beads of 2mm diameter were placed on the pig lung for quantitative measure of the image quality. Without gating, the beads were blurred to 3.75mm during a 3s tomosynthesis acquisition. When gated to the end of the inhalation and exhalation phase the detected bead size reduced to 2.25mm, much closer to the actual bead size. With gating the observed airway edges are much sharper and more visible structural details in the lung. Our results demonstrate the feasibility of prospective gating in the s-DCT, which substantially reduces image blur associated with lung motion.

9412-151, Session PSMon

Anti-scatter grid artifact elimination for high resolution x-ray imaging CMOS detectors.

Raman Rana, Vivek Singh, Amit Jain, Daniel R. Bednarek, Stephen Rudin, Toshiba Stroke Research Ctr. (United States)

Higher resolution in dynamic radiological imaging such as angiography is increasingly being demanded by clinicians; however, when standard anti-scatter grids are used with such new high resolution detectors, grid-line artifacts become more apparent resulting in increased structured noise that may overcome the contrast signal improvement benefits of the scatter-reducing grid. Although grid-lines may in theory be eliminated by dividing the image of a patient taken with the grid by a reference image of a uniform attenuator obtained prior to the clinical image, unless the additive scatter contribution is subtracted in real-time from the dynamic clinical image sequence before the division by the reference image is made, severe grid-line artifacts may remain.

To investigate grid-line elimination, a stationary Smit Rontgen X-ray grid (line density: 70 lines/cm, grid ratio 13:1) was used with both a 75 micron-pixel CMOS detector and a standard 194 micron-pixel flat panel detector (FPD) to image an artery block insert placed in a modified uniform frontal head phantom for a 15 x 15cm FOV.

Contrast and contrast-to-noise ratio (CNR) were measured with and without scatter subtraction prior to grid-line correction. The fixed pattern noise caused by the grid was substantially higher for the CMOS detector compared to the FPD and caused a severe reduction of CNR. However, when

the further scatter subtraction corrective method was used the removal of the fixed pattern noise (grid artifacts) became evident resulting in images with improved CNR.

9412-152, Session PSMon

A combination of spatial and recursive temporal filtering for noise reduction when using region of interest (ROI) fluoroscopy for patient dose reduction in image guided vascular interventions with significant anatomical motion

Swetadri Vasan Setlur Nagesh, Parag Khobragade, Ciprian N. Ionita, Daniel R. Bednarek, Stephen Rudin, Toshiba Stroke and Vascular Research Ctr. (United States)

While x-ray based image-guided vascular interventions are currently the most preferred method of treating disorders such as stroke, arterial stenosis, and embolisms because they are minimally invasive, the x-ray exposure to the patient could cause harmful effects such as cancer and tissue damage. ROI fluoroscopy reduces patient dose by differentially attenuating the incident x-rays outside the region-of-interest. To reduce the noise in the dose-reduced regions previously recursive temporal filtering was successfully demonstrated for neurovascular interventions. However, in cardiac interventions, anatomical motion is significant and recursive filtering could cause blur. In this work the effects of three noise-reduction schemes, including recursive temporal filtering, spatial mean filtering, and a combination of spatial and recursive temporal filtering, was investigated in a simulated ROI dose-reduced cardiac intervention.

First a model to simulate the aortic arch and its movement was built. A coronary stent was used to simulate a bio-prosthetic valve used in TAVR procedures and was deployed under dose-reduced ROI fluoroscopy. The images were then retrospectively processed for noise reduction in the periphery, using recursive temporal filtering, spatial filtering and a combination of both.

Quantitative metrics for all three noise reduction schemes are calculated and are presented as results. From these it can be concluded that with significant anatomical motion, a combination of spatial and recursive temporal filtering scheme is best suited for reducing the excess quantum noise in the periphery. This new noise-reduction technique in combination with ROI fluoroscopy has the potential for substantial patient-dose savings in cardiac interventions.

9412-153, Session PSMon

Directional information of the simultaneously active x-ray sources and fast CT reconstruction

Sajib K. Saha, Murat Tahtali, Andrew J. Lambert, Mark R. Pickering, UNSW Canberra (Australia)

This paper puts emphasis on real data reconstruction using a novel simultaneous CT capture method where a physical 3D phantom consisting of simple geometric shapes was used for the experiment. For a successful reconstruction of the physical phantom, precise calibration of the set up is required. Targeting better reconstruction from minimal number of sweeps, the sparsity prior CT reconstruction algorithm proposed by authors in an earlier work has been adapted to work in conjunction with the simultaneous CT capture modality. Along with critical evaluations of the experimental findings, optimal parameter settings to achieve a given reconstruction resolution are investigated.

9412-154, Session PSMon

A study on quality improvement of x-ray imaging of the respiratory-system based on a new image processing technique

Jun Torii, Yuichi Nagai, Tatsuya Horita, Yuuji Matsumoto, Takehiro Izumo, Mayumi Kitagawa, Kanyu Ihara, National Cancer Ctr. Hospital East (Japan); Tadashi Nakamura, Wataru Mukoyoshi, Kounosuke Tennmei, Suzuki Katsumi, Akio Hara, Hitachi Medical Corp. (Japan); Shinji Sasada, Tomohiko Aso, National Cancer Ctr. Hospital East (Japan)

[Purpose]

New noise reduction processing, ANR (Adaptive Noise Reduction), was announced in SPIE last year. ANR is a new image processing technique which is capable of extracting and reducing noise components regardless of moving objects in fluoroscopy images. Therefore, we have developed new image processing technique, MTNR (Motion Tracking Noise Reduction) for decreasing image lags as well as noise. In this report, we will explain the effect of MTNR by comparing the performance of MTNR images (MTNR) and ANR + Recursive filter-applied images (ANR + Recursive filter).

[Methods]

Sharpness and noise reduction effect of images by MTNR were measured using MTF (Modulation Transfer Function) and NPS (Noise Power Spectrum).Evaluation on patient exposure dose reduction was also performed, based on noise reduction effect by the application of ANR. As for the evaluation method, metal wires of different sizes on the rotating phantoms were moved at a constant speed. After this, one still image was taken out of a fluoroscopy image, and an amount of its image lags was compared between ANR and MTNR. MTNR-applied images on respiratory inspection were compared with ANR images and visually evaluated by 3 senior bronchoscopists and 4 radiological technicians.

[Results]

From the results of MTF and NPS, it was confirmed that MTNR can reduce noise components significantly while maintaining the resolution equivalent to ANR. It was confirmed by measurement using added filters that MTNR images have weaker NPS and improved granularity than ANR images, even if the patient exposure dose is reduced to approximately 50% at a maximum. When moved per 4 pixels / frame, we were able to obtain 1.75 times higher signal intensity than that of ANR without movement. Image lags were generated in ANR, whereas none generated in MTNR. When fast movement of 8 pixels / frame occurred, we were able to obtain 2.3 times higher signal intensity than that of ANR. The effect of MTNR was more apparent compared to slow movement. Since noise was reduced and image lag due to movement decreased, MTNR images were superior to ANR images concerning a recognition rate of lesions and visibility of the device.

[Conclusion]

We confirmed that MTNR processing developed for X-ray fluoroscopy images has potential of shortening the examination time and improving the proper diagnosis rate by reducing not only noise but also image lag. Furthermore, we confirmed that it even has potential for contributing to patient exposure dose reduction.

9412-155, Session PSMon

Anatomy-based transmission factors for technique optimization in portable chest x-ray

Christopher L. Liptak, Cleveland State Univ. (United States); W. Paul Segars, Duke Univ. Medical Ctr. (United States); Frank D. Dong, The Cleveland Clinic (United States); Xiang Li, Cleveland State Univ. (United States)

Currently, portable x-ray examinations do not employ automatic exposure

control (AEC). To aid in the design of a size-specific technique chart, acrylic slabs of various thicknesses are often used to estimate x-ray transmission factors for patients of various body thicknesses. This approach, while simple, does not account for patient anatomy, tissue heterogeneity, and the attenuation properties of the human body. To better account for these factors, in this work, we determined x-ray transmission factors using computational patient models that are anatomically realistic. A Monte Carlo program was developed to model a portable x-ray system. Detailed modeling was done of the x-ray spectrum, detector positioning, collimation, and source-to-detector distance. Simulations were performed using 18 computational patient models from the extended cardiac-torso (XCAT) family (9 males, 9 females; age range: 2-58 years; weight range: 12-117 kg). The ratio of air kerma at the detector with and without a patient model was calculated as the transmission factor. The transmission factor decreased exponentially with increasing patient thickness. For the range of patient thicknesses examined (12-28 cm), the transmission factor ranged from approximately 25% to 2.8% when the air kerma used in the calculation represented an average over the entire imaging field of view. The transmission factor ranged from approximately 25% to 5.2% when the air kerma used in the calculation represented the average signals from two discrete AEC cells. These exponential relationships can be used to optimize imaging techniques for patients of various body thicknesses to aid in the design of clinical technique charts.

9412-156, Session PSMon

Low dose scatter correction for digital chest tomosynthesis

Christina R. Inscoe, Gongting Wu, Jing Shan, Yueh Z. Lee, Otto Zhou, Jianping Lu, The Univ. of North Carolina at Chapel Hill (United States)

Digital chest tomosynthesis (DCT) provides superior image quality and depth information for thoracic imaging at relatively low dose. The presence of strong photon scatter, however, degrades the image quality. In most chest radiography, anti-scatter grids are used. However, the grid also blocks a large fraction of the primary beam photons thus leading to a significantly higher imaging dose for patients. Previously, we have proposed an efficient low dose scatter correction technique using a primary beam sampling apparatus. We implemented the technique in stationary digital breast tomosynthesis the technique, and found the method to be efficient in correcting patient-specific scatter with only 3% increase in dose. In this paper we reported the feasibility study of applying the same technique to stationary chest tomosynthesis system. This investigation was performed utilizing phantom and cadaver subjects. The method involves an initial conventional tomosynthesis scan of the object. A lead plate with an array of holes, or primary sampling apparatus (PSA), was placed on top of the object. A second tomosynthesis scan is performed to measure the primary (scatter-free) transmission. This PSA data was used with the full-field projections to compute the scatter, which was then interpolated to full-field scatter maps unique to each projection angle. Full-field projection images were scatter corrected prior to reconstruction. Projections and reconstruction slices were evaluated and the correction method was found to be effective at improving image quality and practical for clinical implementation.

9412-157, Session PSMon

Signal uniformity of mammography systems and its impact on test results from contrast detail phantoms

Marcus Kaar, Medizinische Univ. Wien (Austria) and AGES GmbH (Austria); Friedrich Semturs, AGES GmbH (Austria) and Medizinische Univ. Wien (Austria); Johann Hummel, Rainer Hoffmann, Michael Figl, Medizinische Univ. Wien (Austria)

Technical quality assurance (TQA) procedures for mammography systems usually include tests with a contrast-detail phantom. These phantoms contain multiple objects of varying dimensions arranged on a flat body. Exposures of the phantom are then evaluated by an observer, either human or software.

One well-known issue of this method is that dose distribution is not uniform across the image area of any mammography system, mainly due to the heel effect. The purpose of this work is to investigate to what extent image quality differs across the detector plane.

We analyze a total of 320 homogenous mammography exposures from 32 radiology institutes. Systems of different models and manufacturers, both computed radiography (CR) and direct radiography (DR) are included. All images were taken from field installations operated within the nationwide Austrian mammography screening program, which includes mandatory continuous TQA.

We calculate signal-to-noise ratios (SNR) for 15 regions of interest arranged to cover the area of the phantom. We define the 'signal range' of an image and compare this value categorized by technologies. We found the deviations of SNR greater in anterior-posterior than in lateral direction. SNR ranges are significantly higher for CR systems than for DR systems.

9412-158, Session PSMon

Signal and noise analysis of flat-panel sandwich detectors for single-shot dual-energy x-ray imagnig

Dong Woon Kim, Pusan National Univ. (Korea, Republic of); Ho Kyung Kim, Pusan National Univ. (Korea, Republic of) and Ctr. for Advanced Medical Engineering (Korea, Republic of); Hanbean Youn, Seungman Yun, Jong Chul Han, Junwoo Kim, Soohwa Kam, Pusan National Univ. (Korea, Republic of); Jesse Tanguay, The Univ. of British Columbia (Canada); Ian A. Cunningham, Robarts Research Institute, Western Univ. (Canada)

The single-shot approach may be preferable to conventional dual-shot methods when imaging speed or insensitivity to motion artifacts is a primary concern. We present a simple cascaded-systems model of single-shot flat-panel sandwich detectors. The model includes direct interaction of x-rays in photodiodes that is unavoidable in the sandwich structure with a corresponding potential increase in image noise. The analytical model is supported by the Monte Carlo approaches. The analytical and Monte Carlo models are validated in comparison with the experimental. This study explores the optimal sandwich detector design and operation parameters.

9412-159, Session PSMon

Exposure dose reduction for the high energy spectrum in the photon counting mammography: simulation study based on Japanese breast glandularity and thickness

Naoko Niwa, Misaki Yamazaki, Yoshie Kodera, Nagoya Univ. (Japan); Mika Yamamuro, Kanako Yamada, Yoshiyuki Asai, Koji Yamada, Kinki Univ. Hospital (Japan)

Recently, digital mammography with photon counting technology utilizing silicon device has been developed. With the aim of reducing exposure dose, we have proposed a new mammography system that uses a cadmium zinc telluride (CZT) photon counting detector. In addition, we also propose a high X-ray energy spectrum with tungsten/barium (W/Ba) as a target/filter. The effectiveness of the W/Ba spectrum in terms of image quality and dose distribution is then evaluated using a Monte Carlo simulation.

The proposed photon counting system with the W/Ba spectrum is

compared a conventional flat panel detector system with a molybdenum/molybdenum (Mo/Mo) spectrum. The dose distributions in a breast model phantom are measured and the contrast-to-noise ratio (CNR) is calculated from simulation images using acrylic steps of polymethyl methacrylate (PMMA). This breast model phantom composed of various glandularities and thickness that determined using Japanese clinical mammograms.

It was found that values of the CNR of the W/Ba system were higher than those of the conventional system. The surface dose was reduced by more than 60 % compared to the conventional system. The number of incident photons to the detector was larger using the W/Ba system, and thus the amount of noise was decreased in comparison with the conventional system. Therefore, the high energy spectrum yielded CNR values equivalent to those obtained using the conventional spectrum, while allowing a considerable reduction in the dose at the breast surface.

9412-160, Session PSMon

Focal spot blooming and the influence of tube current on high contrast spatial resolution

Joshua Grimes, Mayo Clinic (United States); Xinhui Duan, The Univ. of Texas Southwestern Medical Ctr. at Dallas (United States); Lifeng Yu, Shuai Leng, Cynthia H. McCollough, Mayo Clinic (United States)

The objective of this work was to investigate the effect of focal spot blooming on high contrast spatial resolution of two CT scanners, including one scanner equipped with focal spot shaping technology. The bar pattern module of the ACR CT phantom was scanned on the Siemens Definition Flash (scanner A) and Force (scanner B) scanners. The x-ray tube of scanner B has been designed to minimize focal spot blooming effects. On each scanner, the tube current was varied from 100 mA to the maximum mA available at 70 kV and 120 kV. In-house, automatic software for drawing profiles through each bar pattern was used to determine the highest visible frequency in images from each acquisition.

Increasing mA did not change the highest visible frequency bar pattern on either system, but it did lead to a large decrease in peak height and noticeably blurrier images on scanner A. At 70 kV and 500 mA on scanner A, average peak height of the profile drawn through the 10 line pairs/cm bar pattern dropped to 24% of the average peak height at 200 mA. Using scanner B at 70 kV, average peak height at 1300 mA was only 5% less than the average peak height at 200 mA.

Even with the much wider operating range of tube current available on scanner B, focal spot blooming effects were considerably reduced compared to these effects on scanner A, indicating that dynamic focal spot shaping is important for maintaining spatial resolution as mA and kV change.

9412-162, Session PSMon

The effect of motion blur on the accuracy of wrist joint kinematics detection from 4D-CT scans

Geert J. Streekstra, Jim Visschers, Guido de Haan, Johannes G. G. Dobbe, Academisch Medisch Centrum (Netherlands)

Recent developments in 4D CT acquisition techniques enable detection of kinematics of carpal bones in the wrist joint. Detection of carpal kinematics requires the patient to move the wrist while multiple 3D CT scans are acquired. When a patient moves his wrist too fast, individual scans will become blurry and therefore unusable for kinematics detection.

To investigate the effect of wrist motion on wrist joint kinematics estimation we made 4D CT acquisitions of a phantom, representing a wrist joint, while moving with known rotational speed. For this purpose we used a

modified lung puncture protocol on a regular Philips Brilliance 64 slice CT scanner. The wrist phantom was created by segmenting a wrists' anatomy from a CT-scan and subsequent 3D printing by additive manufacturing. Joint kinematics was estimated by 4D image analysis methods involving segmentation of wrist bones from a static CT scan and image registration of the segmented bones to the time frames in the 4D scan.

The experiments reveal that, within a physiological range of carpal bone velocities, the accuracy of joint kinematics estimation are in the order of 1 degree for rotational and 0.2 mm for translational parameters. Systematic errors in kinematical parameters increase slightly with rotational speed.

The limited influence of wrist joint motion on kinematic parameters ensures accurate estimation of carpal bone kinematics with regular 64 slice 4D CT scanners in patients.

9412-163, Session PSMon

Construction of realistic liver phantoms from patient images using 3D printer and its application in CT image quality assessment

Shuai Leng, Lifeng Yu, Thomas J. Vrieze, Joel Kuhlmann, Baiyu Chen, Cynthia H. McCollough, Mayo Clinic (United States)

The purpose of this study is to use 3D printing techniques to construct a realistic liver phantom with heterogeneous background and anatomic structures from patient CT images, and to use the phantom to assess image quality in filtered backprojection and iterative reconstruction algorithms. Patient CT images were segmented into liver tissues, contrast-enhanced vessels, and liver lesions using commercial software, based on which stereolithography (STL) files were created. A 3D liver phantom was printed using a commercial 3D printer after assigning different printing materials to each object to simulate appropriate attenuation of each segmented object. As high opacity materials are not available for the printer, we printed hollow vessels and filled them with iodine solutions of adjusted concentration to represent enhance levels in contrast-enhanced liver scans. The printed phantom was then placed in a 35 x 26 cm oblong-shaped water phantom and scanned repeatedly at 4 dose levels. Images were reconstructed using standard filtered backprojection and an iterative reconstruction algorithm with 3 different strength settings. Heterogeneous liver background were observed from the CT images and the difference in CT numbers between lesions and background were representative for low contrast lesions in liver CT studies. CT numbers in vessels filled with iodine solutions represented the enhancement of liver arteries and veins. Images were run through a Channelized Hotelling model observer with Garbor channels and ROC analysis was performed. The AUC values showed performance improvement using the iterative reconstruction algorithm and the amount of improvement increased with strength setting.

9412-164, Session PSMon

A comparison of material decomposition techniques for dual-energy CT colonography

Radin A. Nasirudin, Technische Univ. München (Germany); Rie Tachibana, Janne J. Näppi, Massachusetts General Hospital (United States); Felix K. Kopp, Technische Univ. München (Germany); Kai Mei, Ernst J. Rummeny, Technische Univ. München (Germany); Hiroyuki Yoshida, Massachusetts General Hospital (United States); Peter B. Noël, Technische Univ. München (Germany)

In recent years, dual-energy computed tomography (DECT) has been widely used in the clinical routine due to improved diagnostics capability from

additional spectral information. One promising application for DECT is CT colonography (CTC) in combination with computer-aided diagnosis (CAD) for detection of lesions and polyps. While CAD has demonstrated in the past that it is able to detect small polyps, its performance is highly dependent on the quality of the input data. The presence of artifacts such as beam-hardening and noise in ultra-low-dose CTC may severely degrade detection performances of small polyps. In this work, we investigate and compare virtual monochromatic images, generated by image-based decomposition and projection-based decomposition, with respect to CAD performance. In the image-based method, reconstructed images are firstly decomposed into water and iodine, before the virtual monochromatic images are calculated. On the contrary, in the projection-based method, the projection data are first decomposed before calculation of virtual monochromatic projection and reconstruction. Both material decomposition methods are evaluated with regards to the accuracy of iodine detection. Further the performance of the virtual monochromatic images is qualitatively and quantitatively assessed. Preliminary results show that the projection-based technique does not only have a more accurate detection of iodine, but also delivers virtual monochromatic images of with reduced beam hardening artifacts in comparison to the image-based technique. With regards to the CAD performance, the projection-based method yields an improved detection performance of polyps in comparison to that of the image-based method.

9412-165, Session PSMon

Conditional-likelihood approach to material decomposition in spectral absorption-based or phase-contrast CT

Pavlo Baturin, Carestream Health Technology and Innovation Ctr. (United States)

Material decomposition in absorption-based X-ray CT imaging suffers certain inefficiencies when differentiating among soft tissue materials. To address this problem, decomposition techniques turn to spectral CT, which has gained popularity over the last few years. Although proven to be more effective, such techniques are primarily limited to the identification of contrast agents, and soft and bone-like materials. In this work, we introduce a novel conditional-likelihood, material-decomposition method capable of identifying any type of material in the object scanned by spectral CT. The method takes advantage of the statistical independence of spectral data to assign likelihood values to each of the materials on a pixel-by-pixel basis. It results in likelihood images for each material, which can be further processed by setting certain conditions or thresholds to yield a final material-diagnostic image. The method can also utilize phase-contrast CT (PCI) data, where measured absorption and phase-shift information can be treated as statistically independent datasets. In this, the following cases were simulated: (i) single-scan PCI CT, (ii) spectral PCI CT, (iii) absorption-based spectral CT, and (iv) single-scan PCI CT with an added tumor mass. All cases were analyzed using a digital breast phantom; although, any other objects or materials can be used instead. As a result, all materials were identified, as expected, according to their assignment in the digital phantom. Especially materials with similar attenuation or phase-shift values (e.g., glandular tissue, skin, and tumor masses) were successfully differentiated by the likelihood approach.

9412-166, Session PSMon

Quantitative assessment of motion occurring during shuttle mode computed tomography (CT) acquisitions for body perfusion imaging applications

Payel Ghosh, The Univ. of Texas M.D. Anderson Cancer Ctr. (United States); Adam G. Chandler, GE Healthcare (United States); Emre Altinmakas, John Rong, Chaan Ng, The Univ. of Texas M.D. Anderson Cancer Ctr. (United States)

We assessed the feasibility of the new shuttle-mode CT technology (where the CT table is moved back and forth during scanning) for body tumor perfusion applications. The study was conducted using shuttle-mode CT scans from three patients with lung or liver tumors. The acquisitions were obtained without IV contrast medium on a GE 750HD CT scanner (GE Healthcare, Waukesha, WI). The shuttle-mode acquisitions consisted of 10 phases with two non-overlapping bed locations (kV-120, mA-220, 2.8s). The reference scan was acquired for each bed location before shuttling (phase 0). Each bed location scan consisted of 8 slices covering 40 mm in the z-direction, which is double the volume-of-tissue that can be evaluated using conventional CT.

We assessed the organ motion that occurs due to shuttling by computing the distance between manually identified fiducial points between-bed-location scans, and between-phase scans. Motion correction was performed using three-dimensional (3D) non-rigid registration software called NiftyReg. The registration results were evaluated by comparing the closeness of the registered images to the reference image.

The between-phase motion was found to be more prominent in shuttle-mode acquisitions than between-bed-location motion with a maximum distance of 7.9 mm from the reference phase. The between-bed location movement was found to be 0.43% (~ 0.75 mm) of the reference phase. Visual validation of results showed well-registered organs-of-interest; however quantitative validation showed an improvement of 1.3 mm between-phase distance and 0.03% between-bed location distance post-registration. The exploration of more representative fiducial points for registration validation is a subject of future work.

9412-168, Session PSMon

Model based iterative reconstruction IMR gives possibility to evaluate thinner slice thicknesses than conventional iterative reconstruction iDose4 – a phantom study using Philips ICT

Marie-Louise Aurumskjöld, Scanias Univ. Hospital (Sweden); Kristina Norrgren, Philips Healthcare (Sweden); Anders Tingberg, Scanias Univ Hospital (Sweden); Marcus Söderberg, Scanias Univ. Hospital (Sweden)

Computed tomography is one of the most important equipments in a radiological department, which produces images with high confidence and it is often available all hours of the day. CT provides a lot of information and can give high radiation dose. One of the measures made to reduce the radiation dose is to use advanced image reconstruction methods.

This study is made on a Philips Brilliance iCT scanner equipped with iterative reconstruction iDose4 and model-based iterative reconstruction IMR. The aim of the study is to investigate if model-based reconstruction (IMR) gives possibility to use thinner slice thickness to increase the resolution due to the absence of noise and if it is possible to also reduce partial volume artefacts using thinner slices. To evaluate image quality both an objective and a subjective method were used. The objective measurements were done using an image quality phantom (Catphan 600, Phantom Laboratory Inc) and direct measurements in the phantom using AutoQALiteTM and ImageJ software. The subjective evaluaton was done on an anthropomorphic phantom (CTU-41, Kyoto Kagaku, Kyoto, Japan). Subjective method was done with observers using the viewing and scoring software ViewDex v2.0 (Viewer for Digital Evaluation of X-ray images). Thinner slice thickness combined with IMR compared to standard slice thickness with iDose4 can improve image quality and diagnostic confidence. IMR gives strong noise reduction and enhanced low contrast thereby enable to select thinner slice thickness. Usually it is a balance between resolution and noise as they work against each other. Another positive effect with thinner slice thickness is that partial volume artefacts is also reduced.

9412-169, Session PSMon

Evaluation of imaging characteristics in CTDI phantom size on contrast imaging

Pil-Hyun Jeon, Yonsei Univ. (Korea, Republic of) and Wonju Severance Christian Hospital (Korea, Republic of); Hee-Joung Kim, Yonsei Univ. (Korea, Republic of); Seong-Su Jeon, Won-Hyung Lee, Yonsei Univ. (Korea, Republic of) and Wonju Severance Christian Hospital (Korea, Republic of)

Recently, there have been several physics and clinical studies on the use of lower tube potentials in CT imaging, with the purpose of improving image quality or further reducing radiation dose. We investigated an experimental study using a series of different sized, PMMA phantoms, demonstrating the potential of use proposed general strategy for dose reduction and to distinguish component of plaque by imaging their energy responses using CT. We investigated the relationship between different sizes of cylinderic PMMA-equivalent phantoms with diameter of 12, 16, 20, 24, and 32 cm and used contrast at various tube voltages (80, 100, 120, and 140 kVp) using a 16–detector row CT scanner. The contrast represented CT numbers as different materials for the water, calcium chloride, and iodine. Phantom insertions also allow quantitative measures of image noise, contrast, contrast-to-noise ratio (CNR) and figure of merit (FOM). When evaluating FOM, it was found that the lower kVp provided the highest CNR. An experimental study was performed to demonstrate reduced dose for both dose efficient and practically feasible for different patient sizes and diagnostic tasks by relating achievable CNR and the volume CT dose index (CTDIvol). The use of spectra optimized to the specific application could provide further improvements of distinguishing iodine, calcium and plaque component for patient size. The purpose of this study was to evaluate variations in image noise and contrast using different tube potentials in a CTDI phantom on contrast imaging.

9412-170, Session PSMon

Scatter correction of vessel dropout behind highly attenuating structures in 4D-DSA

James R. Hermus, Charles A. Mistretta, Timothy P. Szczykutowicz, Univ. of Wisconsin-Madison (United States)

Purpose: In Computed Tomographic (CT) image reconstruction for 4 dimensional digital subtraction angiography (4D-DSA), loss of vessel contrast has been observed behind highly attenuating anatomy, such as large contrast filled aneurysms. Although this typically occurs only in a limited range of projection angles, the observed contrast time course can be altered. In this work we propose an algorithm to correct for highly attenuating anatomy within the fill projection data, ie. aneurysms. Methods: The algorithm uses the 3D-DSA to create a correction volume that is multiplied by the 4D-DSA volume returning the signal in the location of the volume where contrast was lost. The algorithm was designed to correct for highly attenuating material in the fill volume only, however with alterations to a single step of the algorithm, artifacts due to highly attenuating material in the mask volume (ie. dental implants) can be alleviated. Results: We successfully applied our algorithm to a case of vessel dropout due to the presence of a largely attenuating aneurysm. The performance was qualified visually as the affected vessel no longer dropped out on corrected 4D-DSA time frames and quantified by plotting the signal intensity along the vessel. Our analysis demonstrated our correction does not alter vessel signal values outside of the vessel drop out region but does increase the vessel values within the dropout region as expected. Conclusions: We have demonstrated that this correction algorithm acts to correct vessel dropout in areas with highly attenuating materials.

9412-171, Session PSMon

Region of interest cone beam computed tomography (ROI CBCT) with a high resolution CMOS detector

Amit Jain, H. Takemoto, Michael D. Silver, Toshiba Medical Research Institute USA (United States); Swetadri Vasan Setlur Nagesh, Ciprian N. Ionita, Daniel R. Bednarek, Stephen Rudin, Toshiba Stroke and Vascular Research Ctr. (United States)

Cone beam computed tomography (CBCT) with rotational gantries that have standard flat panel detectors are widely used for the 3D rendering of vascular structures generated using Feldkamp cone beam reconstruction algorithms. One of the inherent limitations of these systems is limited resolution (<3 lp/mm). There are systems available with higher resolution but their small FOV limits them to small animal imaging only.

In this work, we report region-of-interest (ROI) CBCT with a high resolution CMOS detector (75μm pixels, 600μm HR-CsI, FOV-7x7cm) mounted with motorized detector changer on a commercial FPD-based C-arm angiography gantry (194μm pixels, 600μm HL-CsI). A head phantom and Wingspan neuro stents were imaged with both detectors. For each detector a total of 209 images were acquired in a rotational protocol. The technique parameters chosen by the FPD were used for the CMOS detector; however, the FPD had an anti-scatter grid while the CMOS did not. Incident scatter was kept the same for both detector assemblies with identical collimator settings.

The FPD images were reconstructed for the full FOV (20x20cm) and for the reduced FOV equal to 7x7cm (for comparison with the CMOS). Although the reconstructed images from the CMOS detector demonstrated comparable contrast to the FPD images, the reconstructed 3D images of the neuro stent clearly showed that the CMOS detector improved delineation of smaller objects such as the stent struts (~70μm) compared to the FPD. Further development and the potential for substantial clinical impact are suggested.

9412-172, Session PSMon

Volume-of-interest reconstruction from severely truncated data in dental cone-beam CT

Zheng Zhang, The Univ. of Chicago Medical Ctr. (United States); Budi Kusnoto, Univ. of Illinois at Chicago (United States); Xiao Han, Emil Y. Sidky, Xiaochuan Pan, The Univ. of Chicago Medical Ctr. (United States)

As cone-beam computed tomography (CBCT) has gained popularity rapidly in dental imaging applications in the past two decades, radiation dose in CBCT imaging remains a potential, health concern to the patients. It is a common practice in dental CBCT imaging that only a small volume of interest (VOI) containing the teeth of interest is illuminated, thus substantially lowering imaging radiation dose. However, this would yield data with severe truncations along both transverse and longitudinal directions. Despite the fact that images within the VOI reconstructed from truncated data can be of some practical utility, they often are compromised significantly by truncation artifacts. In this work, we investigate optimization-based reconstruction algorithms for VOI image reconstruction from CBCT data of dental patients containing severe truncations. In an attempt to further reduce imaging dose, we also investigate optimization-based image reconstruction from severely truncated data collected at projection views substantially fewer than those used in clinical dental applications. Results of our study show that appropriately designed optimization-based reconstruction can yield VOI images with reduced truncation artifacts, and that, when reconstructing from only one half, or even one quarter, of clinical data, it can also produce VOI images comparable to that of clinical images in terms of visualization and clinical-task utility.

9412-173, Session PSMon

Implementation of interior micro-CT on a carbon nanotube dynamic micro-CT scanner for lower radiation dose

Hao Gong, Virginia Polytechnic Institute and State Univ. (United States); Jianping Lu, Otto Zhou, Univ of North Carolina at Chapel Hill (United States); Guohua Cao, Virginia Polytechnic Institute and State Univ. (United States)

Interior micro-computed tomography (micro-CT) produces exact tomographic images of an interior region-of-interest (ROI) embedded within an object from truncated projection data. It holds promises for many biomedical applications with significantly reduced radiation doses. Here, we present our first implementation of an interior micro-CT system using a carbon nanotube (CNT) field-emission micro-focus x-ray source. The system has two modes – interior micro-CT mode and global micro-CT mode, which is realized with a detachable x-ray beam collimator at the source side. The interior mode has an effective field-of-view (FOV) of 7x7x7 mm3, while for the global mode the FOV is 32x32x32 mm3. We acquired CT data in these two modes from a mouse-size phantom and a contrast-agent-filled mouse carcass, and compared the reconstructed image qualities and the associated radiation exposures. The images were reconstructed using the simultaneous algebraic reconstruction technique (SART) combined with the total variation minimization (TVM). We found that interior micro-CT can yield image qualities comparable to global micro-CT, while at significantly reduced radiation doses.

9412-174, Session PSMon

Comparison of cone beam artifacts reduction: two pass algorithm vs TV-based CS algorithm

Shinkook Choi, Jongduk Baek, Yonsei Univ. (Korea, Republic of)

In a cone beam computed tomography (CBCT), the severity of the cone beam artifacts is increased as the cone angle increases. To reduce the cone beam artifacts, several modified FDK algorithms and compressed sensing based iterative algorithms have been proposed. In this paper, we used two pass algorithm and Gradient-Projection-Barzilai-Borwein (GPBB) algorithm to reduce the cone beam artifacts, and compared their performance using structural similarity (SSIM) index. In two pass algorithm, it is assumed that the cone beam artifacts are mainly caused by extreme-density(ED) objects, and therefore the algorithm reproduces the cone beam artifacts(i.e., error image) produced by ED objects, and then subtract it from the original image. GPBB algorithm is a compressed sensing based iterative algorithm which minimizes an energy function for calculating the gradient projection with the step size determined by the Barzilai-Borwein formulation, therefore it can estimate missing data caused by the cone beam artifacts. To evaluate the performance of two algorithms, we used testing objects consisting of 7 ellipsoids separated along the z direction and cone beam artifacts were generated using 30 degree cone angle. Even though the FDK algorithm produced severe cone beam artifacts with a large cone angle, two pass algorithm reduced the cone beam artifacts with small residual errors caused by inaccuracy of ED objects. In contrast, GPBB algorithm completely removed the cone beam artifacts and restored the original shape of the objects.

9412-175, Session PSMon

A new multi-planar reconstruction method using voxel based beamforming for 3D ultrasound imaging

Hyunseok Ju, Jaehee Song, JInbum Kang, Sogang Univ. (Korea, Republic of); Yangmo Yoo, Sogang Univ. (Korea, Republic of) and Interdisciplinary Program of Integrated Biotechnology, Sogang Univ. (Korea, Republic of)

For multi-planar reconstruction in 3D ultrasound imaging, direct and separable 3D scan conversion (SC) have been used for transforming the ultrasound data acquired in the 3D polar coordinate system to the 3D Cartesian coordinate system. These 3D SC methods can visualize an arbitrary plane for 3D ultrasound volume data. However, they suffer from blurring and blocking artifacts due to resampling during SC. In this paper, a new multi-planar reconstruction method based on voxel based beamforming (VBF) is proposed for reducing blurring and blocking artifacts. In VBF, unlike direct and separable 3D SC, each voxel on an arbitrary imaging plane is directly reconstructed by applying the focusing delay to radio-frequency (RF) data so that the blurring and blocking artifacts can be removed. From the phantom study, the proposed VBF method showed the higher contrast and less blurring compared to the separable and direct 3D SC methods. This result is consistent with the measured information entropy contrast (IEC) values, i.e., 98.9 vs. 42.0 vs. 47.9, respectively. In addition, three 3D SC methods were implemented on a high-end GPU by using CUDA programming. The execution times for the VBF, separable and direct 3D SC methods are 1656.1ms, 1633.3 ms and 1631.4 ms, which are I/O bounded, respectively. These results indicate that the proposed VBF method can improve image quality of 3D ultrasound B-mode imaging by removing blurring and blocking artifacts associated with 3D scan conversion and show the feasibility of pseudo-real-time operation.

9412-176, Session PSMon

Non-invasive thermal IR detection of breast tumor development in vivo

Jason R. Case, Madison A. Young, Didier Dreau, Susan R. Trammell, The Univ. of North Carolina at Charlotte (United States)

In 2013, the American Cancer Society estimated that more than 296,000 women and men would be diagnosed with breast cancer and 40,000 would die from the disease in the U.S. Most breast cancer deaths result from the spread of the disease to vital parts of the body. Because there is no cure once metastatic disease has occurred, early detection is essential for successful treatment. We are developing an enhanced thermal IR (8-10 microns) imaging technique that will provide an additional tool for early detection of breast cancer and could potentially be used to monitor tumor development and response to treatment.

Our high-contrast thermal imaging method is sensitive to the presence of blood vessels associated with tumor growth. Blood absorbs light strongly at 530 nm, while absorption by soft tissues is lower at this wavelength. Illuminating tissue/vessels with a 530 nm LED at low powers warms the blood with respect to the surrounding tissue, providing contrast in the IR images. Our current system provides a spatial resolution of 0.26 mm and 52.5 mm field of view. Using this technique, we have mapped vessels 1-2 cm below heart muscle tissue, a significant improvement over traditional thermal imaging techniques.

In this study, we use a murine model to monitor breast cancer tumor growth. Twenty mice were injected with mammary carcinoma and then imaged two times per week over the course of one month to follow tumor development. We compare our IR imaging results to optical fluorescence imaging obtained over the same time period.

9412-177, Session PSMon

Slice profile distortions in single slice continuously moving table MRI

Saikat Sengupta, David S. Smith, Edward B. Welch, Vanderbilt Univ. (United States)

Continuously Moving Table (CMT) MRI is a rapid imaging technique that allows scanning of extended field of views (FOVs) such as the whole body in a single continuous scan. Single slice imaging is a highly efficient approach to CMT MRI, where data are acquired from a single slice at isocenter with concurrent movement of the patient table. However, the continuous motion of the scanner table and supply of fresh magnetization into the excited slice can introduce deviations in the slice magnetization profile and degrade eventual reconstructed image quality. The goal of this work is to investigate and quantify the distortion in the slice profile as well as to propose future methods to account for this distortion in CMT MRI image reconstruction. CMT MRI with a table speed of 20 mm/sec was implemented on a 3 Tesla whole body MRI scanner, with continuous radial ('helical') data acquisition. Simulations were performed to characterize the transient and steady state slice profiles and magnetization effects. Simulated slice profiles were compared to actual slice profile measurements performed in the scanner. Both simulations and experiments revealed an asymmetric slice profile characterized by a skew towards the lagging edge of the moving table, in contrast to the nominal trapezoidal profile associated with scanning a stationary object. The true excited slice width (FWHM) and pitch of the acquisition was observed to be dependent on table velocity, with larger table speeds resulting in larger slice profile deviations from the nominal shape and smaller slicewidths.

9412-179, Session PSMon

A novel monitoring technique for on-line dose profiling in hadrontherapy treatments

Michela Marafini, Museo Storico della Fisica e Centro Studi e Ricerche Enrico Fermi (Italy)

ParticleTherapy (PT) uses accelerated charged ions for cancer treatment. The high irradiation precision and conformity achievable with heavy ions, enhance the Radio Biological Effectiveness (RBE) of such therapy while helping sparing the surrounding healthy tissues and Organs At Risk (OAR). To fully profit from the improved therapy spatial selectiveness, a novel monitoring technique, capable of providing a high precision in-treatment feedback on the dose release position, is required. We propose a novel approach based on the simultaneous detection of secondary protons and prompt photons that are emitted at large angles and are correlated with the Bragg Peak position and the related dose release.

We will review the measured flux and energy spectra for secondary particles produced by 12C, 4He and 16O ion beams of therapeutical energies impinging on PMMA phantoms. Such measurements shows that the rate of produced particles is large enough to supply the sample needed for online monitor operating providing the required O(mm) spatial resolution. A novel dual mode PT monitor, named DoseProfiler, will be presented. The DoseProfiler, whose final layout has been optimized using a dedicated MonteCarlo simulation based on the aforementioned experimental results, combines a tracker detector made of scintillating fibers and a calorimeter built with pixelated LYSO crystals. Six tracker layers (x-y planes) of squared scintillating fibers, will provide the particle direction information, while the crystals will measure the particle energy. The fibers system detection efficiency and the optical cross talk as well as other preliminary performances obtained with dedicated test beams will be reviewed.

9412-180, Session PSMon

Investigation of optimal acquisition time of myocardial perfusion scintigraphy using cardiac focusing-collimator

Arisa Niwa, Nagoya Univ. Graduate School of Medicine (Japan); Shinji Abe, Nagoya Univ. Hospital (Japan); Naotoshi Fujita, Nagoya Univ. Graduate School of Medicine (Japan); Hidetaka Kono, Nagoya Univ. Hospital (Japan); Tetsuro Odagawa, Yusuke Fujita, Saki Tsuchiya, Katsuhiko Kato, Nagoya Univ. Graduate School of Medicine (Japan)

Recently myocardial perfusion SPECT imaging acquired using cardiac focusing-collimator (CF) has been developed in the field of nuclear cardiology. Previously we have investigated the basic characteristics of CF using physical phantoms. This study was aimed at determining the acquisition time for CF that enables to acquire the SPECT images equivalent to those acquired by the conventional method in 201Tlcl myocardial perfusion SPECT.In this study, Siemens Symbia T6 used by setting the torso phantom, and 201Tlcl solution were enclosed into the left ventricular (LV) myocardium and liver. CF or the low energy high resolution collimator (LEHR) was set on the SPECT equipment. Data acquisitions were made by regarding the center of the phantom as the center of the heart in CF at various acquisition times. Acquired data were reconstructed, and the polar maps were created from the reconstructed images. Coefficient of variation (CV) was calculated as mean counts determined on polar maps and their standard deviations. When CF was used, CV was lower at longer acquisition times. CV calculated from polar map acquired with LEHR was 9.975, and this value was equivalent to CV calculated from the polar map acquired with CF at 7 min of acquisition time. This study concluded that, CV, which is calculated from the SPECT data acquired using CF at 7 min of acquisition time, is equivalent to CV from those acquired by the conventional method using LEHR at 20 min.

9412-181, Session PSMon

Magnetization components of moving nuclear spin under NMR/MRI excitation(I)

Dilip K. De, Justina Achuka, Covenant Univ. (Nigeria)

 n the heart of NMR/MRI Imaging science & technology lie the components of magnetizations (specially My and Mz when rf B1 field is lying along a laboratory axis, say, X-direction). The components and consequently the detected MR signals/images depend in a complicated way on magnetic fields (bias and gradient fields), relaxation times, rf B1 field (pulsed or continuous), relaxation times, blood(nuclear spin) flow velocity and rates, diffusion of spins, density of spins etc. The last four quantities are of clinical importance (for diagnosis of tissues and blood flow estimation) which are to be extracted from the MR images or signals. Understanding of such dependencies clearly is very crucial to the medical diagnosis that depend on MR images/signals. NMR Bloch equations provide coupled differential equations involving the components of magnetization. The simulation of the images done so far has not used the exact correct relationship of the single component My and Mz(which produce signals in a detector) on the above quantities. The main purpose of this work is to develop and show the pathway for finding the true relationship of individual My and Mz component with the said quantities, using the fundamental Bloch equations.

We have adapted two methods (i) operator formalism (ii) gradual elimination of variables from the coupled differential equations to obtain two compact differential equations one containing only My and the other containing only Mz component of the magnetization in presence of rf B1 field and spin flow which can depend on both space and time coordinates. The derived equations are referred to the rotating frame of reference. We have given the transformation equation from rotating frame of reference to the laboratory frame of reference, which can be used to transform the My and Mz components (that can be obtained from the solutions of the compact differential equations) in the rotating frame to that in the

laboratory frame. We have also given expressions for the signal to be expected from either of the magnetization component(depending on detector orientation) .

We have obtained the correct dependence of the single component My and Mz with the above quantities in the rotating frame of reference using the above two approaches. We found that though the two approaches yield two apparently looking different equations for My, on analysis they turn out to give the same equation for My. The same holds for Mz (whose equation is different from that of My). These newly developed equations yield the same known equations for My and Mz in absence of flow of spins (blood in clinical sense) at resonance (CW) in the lboratory frame.

We find that the developed equations are unique and for the first time describe the true relationship between individual single component My,Mz with the above quantities (excluding diffusion and gradient fields). The equations are applicable for both CW and pulsed NMR experiments with or without flow of spins. Our approaches can be extended easily to include gradient fields and diffusion of spins, and to transform to laboratory frame, if needed. We also discuss the methods of application of our equations to two specific cases of MR excitation scheme: Free induction decay and spin echo to obtain the correct expressions for the magnetization components.

PACS: 87.61.Np; 47.63.Cb, 87.19.ug, 87.19.uj

9412-182, Session PSMon

Modeling CZT/CdTe x-ray photon-counting detectors

Andrey V. Makeev, Univ. of Massachusetts Medical School (United States); Miesher Rodriguez, Jimmy Wang, Toshiba Medical Research Institute USA (United States); Stephen J. Glick, Univ. of Massachusetts Medical School (United States)

Semiconductor x-ray photon-counting detectors for computed tomography based on dense, high atomic number materials, such as CZT, CdTe, etc., have demonstrated enhanced performance, compared to conventional energy integrating devices. Despite promising results reported in the literature, there remains a number of issues associated with such detectors, including: inter-pixel charge sharing and fluorescent x-rays, pixel energy threshold variability, pulse-pileup and space charge built-up in the high flux environment. These factors lead to degraded spatial resolution, distorted energy information, count rate limitations, and artifacts in the acquired data. We are developing a model that can be helpful for understanding detector behavior, optimization of operating parameters, and investigating methods of compensation for the degrading factors mentioned above. In this work we present a set of computer tools designed to simulate the photon-counting pulse processing chain.

9412-183, Session PSMon

Statistical bias in material decomposition in low photon statistics region

Paurakh L. Rajbhandary, Norbert J. Pelc, Stanford Univ. (United States)

We show that in material decomposition application, statistical biases in basis material estimates exist due to non-linearity of the system. This effect is more pronounced at lower photon counts. As new scan protocols are pushing the boundary towards increasing number of energy bins and projection paths to maximize information from scans, estimators should be robust against such biases at low photon counts. We present a study of biases as a function of material thicknesses, number of energy bins, and number of projection views. In our study, we find that the bias increases with thicker materials, more number of energy bins and more projection views, as the number of photons per bin is reduced. We find that biases in the two basis materials are negatively correlated. We also propose a projection space based correction method that uses a heuristic

approximation of the bias based on a given sample scan. Using this method, we show improvements in accuracy of material decomposition in projection space as well as in the image space. We find the relative bias in basis materials for our setup to be up to (0.70 ± 0.12) % and (1.43 ± 0.12) % in projection space and image space, respectively. With the bias correction method employed, the relative bias in image space is (0.12 ± 0.17) %.

9412-184, Session PSMon

Reducing the formation of image artifacts during spectroscopic micro-CT acquisitions

Marcus Zuber, Thomas Koenig, Rubaiya Hussain, Elias Hamann, Karlsruher Institut für Technologie (Germany); Rafael Ballabriga Sune, Michael Campbell, CERN (Switzerland); Alex Fauler, Freiburger Materialforschungszentrum (Germany); Michael Fiederle, Freiburger Materialforschungszentrum (Germany) and Karlsruher Institut für Technologie (Germany); Tilo Baumbach, Karlsruher Institut für Technologie (Germany)

Spectroscopic μCT using photon counting detectors is a technology that promises to deliver material-specific images in pre-clinical research. Inherent to such applications is the need for a high spatial resolution, which can only be achieved with small focal spot sizes in the micrometer range. This limits the achievable x-ray fluxes and implies long acquisitions easily exceeding one hour, during which it is paramount to maintain a constant detector response. Given that photon-counting detectors are delicate systems, with each pixel hosting advanced analog and digital circuitry, this can represent a challenging task.

In this contribution, we illustrate our findings on how to reduce image artifacts in CT reconstructions under these conditions. We find that maintaining a constant temperature is a prerequisite to guarantee energy threshold stability. More importantly, we identify varying leakage currents as a significant source to artifact formation when employing compound semiconductor sensors such as CdTe. We conclude with demonstrating the necessity of an adjustable leakage current compensation.

9412-185, Session PSMon

Investigation of a one-step spectral CT reconstruction algorithm for direct inversion into basis material images

Taly Gilat Schmidt, Marquette Univ. (United States); Emil Y. Sidky, The Univ. of Chicago (United States)

Photon-counting detectors with pulse-height analysis have shown promise for improved spectral CT imaging. This study investigated a novel spectral CT reconstruction method that directly estimates basis-material images from the measured energy-bin data (i.e., 'one-step' reconstruction). The proposed algorithm can incorporate constraints to stabilize the reconstruction and potentially reduce noise. The algorithm minimizes the error between the measured energy-bin data and the data estimated from the reconstructed basis images. A total variation (TV) constraint was also investigated for additional noise reduction. The proposed one-step algorithm was applied to simulated data of an anthropomorphic phantom with heterogeneous tissue composition. Reconstructed water, bone, and gadolinium basis images were compared for the proposed one-step algorithm and the conventional `two-step' method of decomposition followed by reconstruction. The unconstrained algorithm provided a 30% to 60% reduction in noise standard deviation compared to the two-step algorithm. The f_tv=0.8 constraint provided a small reduction in noise (~1%) compared to the unconstrained reconstruction. Images reconstructed with the f_tv=0.5 constraint demonstrated 77% to 94% standard deviation reduction compared to the two-step reconstruction,

however with increased blurring. There were no significant differences in the mean values reconstructed by the investigated algorithms. Overall, the proposed one-step spectral CT reconstruction algorithm provided three-material-decomposition basis images with reduced noise compared to the conventional two-step approach. When using a moderate TV constraint factor (f_tv=0.8), a 30%-60% reduction in noise standard deviation was achieved while preserving the edge profile for this simulated phantom.

9412-186, Session PSMon

A photon counting detector model based on increment matrices to simulate statistically correct detector signals

Sebastian Faby, Joscha Maier, David Simons, Heinz-Peter Schlemmer, Deutsches Krebsforschungszentrum (Germany); Michael Lell, Friedrich-Alexander-Univ. Erlangen-Nürnberg (Germany); Marc Kachelriess, Deutsches Krebsforschungszentrum (Germany)

We present a novel increment matrix concept to simulate the correlations in an energy-selective photon counting detector. Correlations between the energy bins of neighboring detector pixels are introduced by scattered and fluorescence photons, together with the broadening of the induced charge clouds as they travel towards the electrodes leading to charge sharing. It is important to generate statistically correct detector signals for the different energy bins to be able to realistically assess the detector performance in various tasks, e.g. material decomposition. Our increment matrix concept describes the counter increases in neighboring pixels on a single event level. Advantages of our model are the fact that much less random numbers are required than simulating single photons and that the increment matrices together with their probabilities have to be generated only once and can be stored for later use. The different occurring increment matrix sets and the corresponding probabilities are simulated using an analytic model of the photon-matter-interactions based on the photoelectric effect and Compton scattering, and the charge cloud drift, featuring thermal diffusion and Coulomb expansion of the charge cloud. First results obtained with this model are evaluated in terms of the spectral response of different detector geometries. Comparisons to published measured data and a parameterized detector model show both a good qualitative and quantitative agreement.

9412-187, Session PSMon

Photon-counting CT: modeling and compensating of spectral distortion effects

Jochen Cammin, Johns Hopkins Univ., School of Medicine (United States); Steffen G. Kappler, Siemens Healthcare (Germany); Thomas Weidinger, Siemens Healthcare (Germany); Katsuyuki Taguchi, Johns Hopkins Univ., School of Medicine (United States)

Spectral CT with photon-counting detectors (PCDs) has the potential to advance diagnostic CT imaging by reducing image noise and dose, by improving contrast and tissue specificity, and by enabling molecular and functional imaging. However, the current PCD technology is limited imperfect energy measurement (spectral response effects, SRE) and count rate non-linearities (pulse pileup effects, PPE) resulting in image artifacts and quantitative inaccuracies for material specification. These limitations can be lifted with image reconstruction algorithms that compensate for both SRE and PPE. A prerequisite for this approach is an accurate model of the count losses and spectral distortions in the PCD. In earlier work we developed a cascaded SRE-PPE model and evaluated it using a physical PCD. In this paper we show the robustness of our approach by evaluating the cascaded SRE-PPE model using simulated data of a faster PCD with smaller pixels and a different pulse shape. We compare paralyzable and non-paralyzable detector models. First, the SRE-PPE model is evaluated at

low and high count rates using two sets of attenuators. Then, the accuracy of the compensation is evaluated by estimating the thicknesses of a subset of the attenuating materials and comparing them to the true thicknesses. The model agrees with the data for a wide range of count rates with COVW = 7.3% for a DLR as large as 44.6%. The estimated attenuator thicknesses agree with the true values within 0.33 standard deviations on average when the full SRE-PPE model is used.

9412-188, Session PSMon

On filtration for high-energy phase-contrast x-ray imaging

Christian Riess, Stanford Univ. (United States); Ashraf Mohamed, Siemens Medical Solutions USA, Inc. (United States); Waldo S. Hinshaw, Rebecca Fahrig, Stanford Univ. (United States)

Phase-sensitive X-ray imaging promises unprecedented soft-tissue contrast and resolution. However, when using the setup in a clinical environment, several practical challenges have to be overcome. The system design that is currently closest to clinical use is the grating-based Talbot-Lau interferometer (GBI).

For patient imaging, requirements are low patient dose, fast imaging times, and a high image quality. For GBI, all of these points jointly benefit from a narrow, yet high-flux, spectrum. Additionally, to penetrate tissue thicknesses at the size of humans, the design energy of the system has to be in the range of 40keV to 100keV. To our knowledge, little research has been done so far to investigate optimum GBI filtration at such high X-ray energies.

In this paper, we study different filtration strategies and its impact on high-energy GBI. Specifically, we compare copper filtration at low peak voltage with equal-absorption, equal-imaging time K-edge filtration of spectra with higher peak voltage under clinically realistic boundary conditions. We specifically focus on a design energy of 59keV, and investigate combinations of tube current, peak voltage, and filtration that lead to equal patient absorption.

Theoretical considerations suggest that the K edge of tantalum provides a transmission pocket at around 59keV, yielding a well-shaped spectrum. Although one can observe a slight visibility benefit from tantalum's K edge, the gain in visibility is not large enough to yield a visibility superior to a copper-filtered spectrum at the investigated equal-absorption configurations.

9412-189, Session PSMon

Single-step, quantitative x-ray differential phase contrast imaging using spectral detection in a coded aperture setup

Mini Das, Zhihua Liang, Univ. of Houston (United States)

In this abstract, we describe the first non-interferometric x-ray phase contrast imaging (PCI) method that uses only a single-measurement step to retrieve with quantitative accuracy absorption, phase and differential phase. Our approach is based on utilizing spectral information from photon counting spectral detectors in conjunction with a coded aperture PCI setting to simplify the x-ray "phase problem" to a one-step method. The method by virtue of being single-step with no motion of any component for a given projection image has significantly high potential to overcome the barriers currently faced by PCI.

9412-190, Session PSMon

Spectral X-ray phase contrast imaging for single-shot absorption and phase retrieval in grating

Zhili Wang, Univ. of Science and Technology of China (China); Naihong Ren, Anhui Huadian Engineering Consultating & Design CO. LTD (China)

X-ray phase contrast imaging using grating interferometry has been attracting increasing attention for its great potential in biomedical imaging and materials science. Especially, X-ray grating interferometry can efficiently generate phase contrast even with conventional tube sources, paving the road for widespread preclinical and clinical applications. Recently, special attention has been paid to quantitative phase retrieval from intensity measurements, which is mandatory to perform phase tomography, etc. In this paper, we demonstrate a single-shot method to quantitatively retrieve absorption and phase shift, by using solutions of spectral linearly approximated intensity equations. By use of energy resolving capability of X-ray photon counting detectors (XPCDs), we obtain a set of intensity measurements within a single exposure. Taking the energy dependence of the absorption and phase shift into consideration, we yield a set of spectral linear equations in terms of two energy independent unknowns. The absorption and shift can then be quantitatively retrieved by use of solutions to the two unknowns. We simulate an energy resolved X-ray grating interferometer using a Cadmium-Zinc-Telluride (CZT) based photon counting detector. The retrieval results are in good agreement with theoretical true values, thus confirmed the feasibility of the presented approach, and its great potential in future preclinical and clinical applications.

9412-191, Session PSMon

Practicable phase contrast techniques with large spot sources

Jonathan C. Petruccelli, Sajid Bashir, Sajjad Tahir, Bushra Kanwal, Carolyn A. MacDonald, Univ. at Albany (United States)

A major limitation to the widespread adoption of phase-contrast techniques is that for tabletop sources the required degree of coherence generally requires a small (10 to 50 μm) source [1] or, for example, multiple images with precision gratings[2]. In this work, two techniques were employed to produce phase contrast from conventional sources in a single image. In the first, a polycapillary optic was employed to create a virtual source from a large spot rotating anode. Phase contrast images obtained with two optics and several pinholes have been analyzed and preliminary results obtained for quantitative phase measurements. Edge-enhancement to noise ratio up to a value of 6.5 was obtained. Conventional absorption and phase images of insect were acquired to see feasibility of phase imaging in biological tissues. A pure phase object was also obtained using a phase attenuation duality approach [3] by taking only a single image.

The second technique is based on recent work of Bennett et al. that utilizes a much coarser grid [4]. Phase is extracted using Fourier processing on a single raw image taken using a focused mammography grid. The effects on the final image of varying grid, object and detector distances, and of a variety of windowing functions, which were used to separate the harmonics, were investigated. Large contrast-enhanced peak-height-to-noise ratios were obtained using easily available scatter rejection grids and a 100 μm spot size source.

9412-192, Session PSMon

Statistical estimation of the directional dependency of subject in visibility-contrast imaging with the x-ray Talbot-Lau interferometer

Takayuki Shibata, Shohei Okubo, Yoshie Kodera, Nagoya Univ. (Japan)

Conventional x-ray images are formed by absorption contrast due to attenuation of x-ray intensity. In recent years, the phase contrast method has highlighted, in which image contrast is decided according to phase shift of x-rays transmitted through an object. The phase contrast method is excellent for visualization of soft tissue, which is difficult to visualize using conventional x-ray imaging. The Talbot-Lau interferometer using phase contrast method developed by Konica Minolta, Inc. There are images of three types can be obtained in the Talbot-Lau interferometer, i.e. absorption image, differential phase-contrast image, and visibility-contrast image. Visibility-contrast image reflects reduction of coherence due to the object's structures. Its well-known feature is the contrast due to the x-ray small-angle scattering. In addition, in the visibility-contrast image, the relationship between the signal intensity and the direction of the subject's structure has been analyzed. Talbot-Lau interferometer only detected the phase shift along the periodic direction of grating due to use the one-dimensional grating. In this study, we focused on how the signal intensity was affected by the direction of the subject structure, and we analyzed the edge signal of the subject. We imaged the acrylic and the aluminum cylinder with the Talbot-Lau interferometer by rotating from 0 degree to 90 degrees with respect to the periodic direction of the grating, and measured their edge signal. Moreover, we statistically estimated the edge signal of aluminum cylinder and compared with the measured value. They correspond with high accuracy.

9412-193, Session PSMon

The quantitative evaluation of the correlation between the magnification and the visibility-contrast value

Shohei Okubo, Nagoya Univ. (Japan); Takayuki Shibata, Yoshie Kodera, Nagoya Univ. (Japan)

Talbot-Lau interferometer, which consists of a conventional x-ray tube, an x-ray detector, and three gratings arranged between them, is a new x-ray imaging system using phase-contrast method for excellent visualization of soft tissue. So, it is expected to be applied to an imaging method for soft tissue in the medical field, such as mammograms. The visibility-contrast image, which is one of the reconstruction images using Talbot-Lau interferometer, is known that the visibility-contrast reflects reduction of coherence that is caused from the x-ray small-angle scattering and the x-ray refraction due to the object's structures. Both phenomena were not distinguished when we evaluated the visibility signal quantitatively before. However, we consider that we should distinguish both phenomena to evaluate it quantitatively. In this study, to evaluate how much the magnification affect the visibility signal, we investigated the variability rate of the visibility signal between the object-position in the height of 0 cm and 56 cm from the diffraction grating in each case of examining the scattering signal and the refraction signal. We measured the edge signal of glass sphere to examine the scattering signal and the internal signal of aluminum cylinder to examine the refraction signal. We can indicate the difference of the variability rate between the edge signal and the internal signal. We tried to estimate the visibility signal in the height of 56 cm from the visibility signal in the height of 0 cm, and we propose the estimation method using magnification.

9412-194, Session PSMon

Complex dark-field contrast in grating-based x-ray phase contrast imaging

Yi Yang, Xiangyang Tang, The Winship Cancer Institute of Emory Univ. (United States)

Under the existing theoretical framework of grating-based x-ray phase contrast imaging, the dark-field contrast refers to the reduction in interference fringe visibility due to small-angle x-ray scattering of the sub-pixel microstructures of an object to be imaged. In addition, the object's sub-pixel microstructures are usually assumed to distribute in space randomly. In this study we focus on investigating, based on the paraxial Fresnel-Kirchhoff theory, how an object's microstructures can also affect the phase of the intensity oscillations. Without assuming a random spatial distribution for the object's sub-pixel microstructures, we derive analytical formulae to characterize the influence of the object's sub-pixel microstructures on grating-based x-ray phase contrast imaging. Then the existing dark-field contrast is generalized into a complex dark-field contrast in a way such that the existing dark-field contrast is just the real part of the complex dark-field contrast, while the effect of the object's sub-pixel microstructures on the phase of the intensity oscillations is the imaginary part. An approximate method based on the phase-attenuation duality at high x-ray energies is proposed to retrieve the imaginary part of the complex dark-field contrast for imaging. Our theoretical analysis and computer simulation study show that the imaginary part of the complex dark-field contrast is more sensitive to the microstructures' asymmetry in shape than the real part, thus an imaging of the imaginary part of the complex dark-field contrast may provide additional information complementary to that corresponding to the attenuation contrast, phase contrast and the existing dark-field contrast.

9412-195, Session PSMon

Improving depth resolution in digital breast tomosynthesis by iterative image reconstruction

Erin G. Roth, Carleton College (United States); David N. Kraemer, Grinnell College (United States); Emil Y. Sidky, Ingrid S. Reiser, Xiaochuan Pan, The Univ. of Chicago Medical Ctr. (United States)

Digital breast tomosynthesis (DBT) is currently enjoying tremendous growth in its application to screening for breast cancer. This is because it addresses a major weakness of mammographic projection imaging; namely, a cancer can be hidden by overlapping fibroglandular tissue structures or the same normal structures can mimic a malignant mass. DBT addresses these issues by acquiring few projections over a limited angle scanning arc that provides some depth resolution. As DBT is a relatively new device, there is potential to improve its performance significantly with improved image reconstruction algorithms. Previously, we reported a variation of adaptive steepest descent - projection onto convex sets (ASD-POCS) for DBT, which employed a finite differencing filter to enhance edges for improving visibility of tissue structures and to allow for volume-of-interest reconstruction. The present work, develops an accurate primal-dual solver for the associated optimization problem and applies it to clinical DBT data. Additionally, we present a singular value decomposition (SVD) analysis to demonstrate the gain in depth resolution for DBT afforded by use of the finite differencing filter.

9412-196, Session PSMon

Physical characterization of photon-counting tomosynthesis

Karl Berggren, Philips Healthcare (Sweden) and KTH Royal Institute of Technology (Sweden); Mats Lundqvist, Björn Cederström, Philips Healthcare (Sweden); Mats E. Danielsson, KTH Royal Institute of Technology (Sweden); Erik Fredenberg, Philips Healthcare (Sweden)

Tomosynthesis and photon-counting spectral imaging are two emerging technologies in mammography, which if combined open up for new applications and potential boosts in sensitivity and specificity. We are developing a Fourier-based framework for quantitative evaluation of image quality in photon-counting spectral tomosynthesis. Simulation tools were developed to propagate the modulation transfer function (MTF) and the noise-power spectrum (NPS), and to calculate the detective quantum efficiency (DQE), which will be crucial for system optimization and to understand the potential benefit of the technology. Procedures to measure the MTF and NPS were developed, applied to verify simulation results, and may be further used to develop tests for quality control. Application of the framework was demonstrated on a prototype photon-counting tomosynthesis system (Philips Healthcare, Sweden). The simulations were effective in predicting measurement results. The NPS exhibited a behavior strongly dominated by the voxel size of the reconstruction algorithm, suggesting that the 3D reconstruction might be a limiting factor in the final image quality. However, the MTF exhibited hardware limited behavior. Further measurements and analysis are ongoing.

9412-197, Session PSMon

Metal artifact reduction in tomosynthesis imaging

Zhaoxia Zhang, Ming Yan, Kun Tao, GE Global Research (China); Xiao Xuan, GE Healthcare (China); John M. Sabol, GE Healthcare (United States); Hao Lai, GE Global Research (United States)

The utility of digital tomosynthesis has been shown for many clinical scenarios including post orthopedic surgery applications. However, two kinds of metal artifacts can influence diagnosis: undershooting and ripple. In this paper, we describe a novel metal artifact reduction (MAR) algorithm to reduce both of these artifacts within the filtered backprojection framework.

First, metal areas that are prone to cause artifacts are identified in the raw projection images. These areas are filled with values similar to those in the local neighborhood. During the filtering step, the filled projection is free of undershooting due to the resulting smooth transition near the metal edge. Finally, the filled area is fused with the raw projection data to recover the metal. Since the metal areas are recognized during the back projection step, anatomy and metal can be distinguished - reducing ripple artifacts.

Phantom and clinical experiments were designed to quantitatively and qualitatively evaluate the algorithms. Based on phantom images with and without metal implants, the Artifact Spread Function (ASF) was used to quantify image quality in the ripple artifact area. The tail of the ASF with MAR decreases from in-plane to out-of-plane, implying a good artifact reduction, while the ASF without MAR remains high over a wider range. An intensity plot was utilized to analyze the edge of undershooting areas. The results illustrates that MAR reduces undershooting while preserving the edge and size of the metal. Clinical images evaluated by physicists and technologists agree with these quantitative results to further demonstrate the algorithm's effectiveness.

9412-198, Session PSMon

Distance driven backprojection image reconstruction in digital tomosysthesis

Nuhad A. Malalla, Shiyu Xu, Ying Chen, Southern Illinois Univ. Carbondale (United States)

In this paper, distance driven (DD) backprojection image reconstruction was investigated for digital tomosysthesis. Digital tomosysthesis is an imaging

technique to produce three dimensional information of the object with low radiation dosage. This paper is a new study of DD backprojection for image reconstruction in digital tomosythesis. Since DD considers that the image pixel and detector cell have width, the convolution operation is used to calculate DD coefficients and the approximation characteristics of some other methods such as ray driven method (RD) can be avoided. For three dimensional cone beam reconstruction, both projected voxel boundaries and detector cells boundaries are mapped to a common plane to estimate the overlap area. The overlap area is estimated by multiplying the overlap length along the (x or y) direction and along z direction. This paper represents a computer simulation result of DD with Maximum Likelihood Expectation Maximization (MLEM) of tomosysthesis reconstruction algorithms. The sequence of projection images were acquired from 25 projections with a total view angle of 48 degrees. DD with MLEM reconstruction results were demonstrated. The computation time in DD with MLEM to provide the reconstruction results is short since the main loop of DD is over x and y intercepts not over the image pixels or detectors cells compared with RD. In clinical applications, both the accuracy and speed of implementation condition are necessary requirements. DD backprojection can mostly satisfy the required conditions. In this paper, line profile along x direction was used to evaluate DD and RD methods.

9412-199, Session PSMon

Detection of lung nodules in chest digital tomosynthesis (CDT): effects of the different angular dose distribution

Byung-Du Jo, Hee-Joung Kim, Young-Jin Lee, Dong-Hoon Lee, Do-Hyeon Kim, Seong-Soo Jin, Shou-Chih Mu, Hye-Mi Kim, Yonsei Univ. (Korea, Republic of)

Chest digital tomosynthesis (CDT) is a recently introduced for better high- and small-contrast lung nodules detection compared to conventional X-ray radiography. In CDT system, several projection views need to be acquired with limited angular range. The acquisition of insufficient number of projection data can degrade the reconstructed image quality. This image degradation easily affected by acquisition parameters such as angular dose distribution, number of projection views and reconstruction algorithm. To investigate the imaging characteristics, we evaluated the impact of the angular dose distribution on image quality by simulation studies with Geant4 Application for Tomographic Emission (GATE). We designed the different angular dose distribution conditions. The results showed that the contrast-to-noise ratio (CNR) improves when exposed the higher dose at central projection views than peripheral views. While it was found that increasing angular dose distribution at central views improved lung nodule detectability, although both peripheral regions slightly suffer from image noise due to low dose distribution. The improvements of CNR by using proposed image acquisition technique suggest possible directions for further improvement of CDT system for high quality lung nodule imaging application.

9412-200, Session PSMon

Evaluation of effective dose with chest digital tomosynthesis system using Monte Carlo simulation

Do-Hyeon Kim, Byung-Du Jo, Young-Jin Lee, Su-Jin Park, Dong-Hoon Lee, Hee-Joung Kim, Yonsei Univ. (Korea, Republic of)

Chest digital tomosynthesis (CDT) system has recently been introduced and studied. This system offers the potential to be a substantial improvement over conventional chest radiography for the lung nodule detection and reduces the radiation dose with limited angle. PCXMC simulation toolkit (STUK, Helsinki, Finland) is most widely used to evaluate radiation dose in CDT system, but this toolkit has two significant limits. Although most commonly used PCXMC is not possible to describe a model for every individual patient and does not describe the accurate X-ray beam spectrum, GATE simulation describes the various size of phantom for every individual patient and proper X-ray spectrum. However, few studies have been conducted to evaluate effective dose in CDT system with the Monte Carlo simulation toolkit using Geant4 Application for Tomographic Emission (GATE). The purpose of this study was to evaluate effective dose in virtual infant chest phantom of posterior-anterior (PA) view in CDT system using GATE simulation. We obtained the effective dose at different tube angle by applying dose actor function in GATE simulation which is commonly used to obtain the medical radiation dosimetry. The results indicated that GATE simulation is useful to estimate distribution of absorbed dose. Consequently, we obtained the acceptable distribution of effective dose at each projection, which we believe GATE simulation can be alternative method of calculating effective dose in CDT applications.

9412-201, Session PSMon

Optimization of a coded aperture coherent scatter spectral imaging system for medical imaging

Joel A. Greenberg, Duke Univ. (United States); Manu N. Lakshmanan, Duke Univ. Medical Ctr. (United States); David J. Brady, Duke Univ. (United States); Anuj J. Kapadia, Duke Univ. Medical Ctr. (United States)

Coherent scatter X-ray imaging, which provides spatially-resolved information about the molecular structure of the material under investigation, yields material-specific contrast that can aid medical diagnosis and inform treatment. In this paper, we demonstrate an imaging approach based on the use of coded apertures (known as coded aperture coherent scatter spectral imaging, or CACSSI) that overcomes the problem of long scan times to provide fast, dose-efficient, high-resolution scatter imaging of biologically-relevant materials. Specifically, we discuss how to optimize a CACSSI system for a particular set of materials, describe and characterize our experimental system, and use the system to demonstrate automated material detection.

9412-202, Session PSMon

Concept and setup for intraoperative imaging of tumorous tissue via attenuated total reflection spectrosocopy with quantum cascade lasers

Florian B. Geiger, Univ. Stuttgart (Germany) and Siemens AG (Germany); Martin Koerdel, Anton Schick, Siemens AG (Germany); Axel Heimann, Johannes Gutenberg-University Mainz (Germany); Kaspar Matiasek, Ludwig Maximilians University (Germany); Alois M. Herkommer, Univ. Stuttgart (Germany)

A major challenge in tumor surgery is the differentiation between normal and malignant tissue. Since an incompletely resected tumor easily leads to recidivism, the gold standard is to remove malignant tissue with a sufficient safety margin and send it to pathology for examination with patho-histological techniques (rapid section diagnosis).

This proceeding, however, exhibits several disadvantages: The removal of additional tissue (safety margin) means additional stress to the patient; the correct interpretation of proper tumor excision relies on the pathologist's experience and the waiting time between resection and pathological result can be more than 45 minutes. This last aspect implies unnecessary occupation of cost-intensive operating room staff as well as longer anesthesia for the patient.

Various research groups state that hyperspectral imaging in the mid-

infrared, especially in the so called fingerprint region, allows spatially resolved discrimination between normal and malignant tissue. All these experiments, though, took place in a laboratory environment and were conducted on dried, ex vivo tissue and on a microscopic scale.

It is therefore our aim to develop a system incorporating the following properties: Intraoperatively and in vivo applicable, measurement time shorter than one minute, based on mid infrared spectroscopy, providing both spectral and spatial information and no use of external fluorescence markers.

Theoretical valuation of different concepts and experimental studies show that a setup based on a tunable Quantum Cascade Laser and Attenuated Total Reflection seems feasible for in vivo tissue discrimination via imaging. This is confirmed by experiments with a first demonstrator.

9412-203, Session PSMon

Scatter-free breast imaging using a monochromator coupled to a pixellated spectroscopic detector

Faith H. Green, Univ. of Surrey (United Kingdom); Matthew C. Veale, Matthew D. Wilson, Paul Seller, Rutherford Appleton Lab. (United Kingdom); James W. Scuffham, The Royal Surrey County Hospital NHS Trust (United Kingdom); Silvia Pani, Univ. of Surrey (United Kingdom)

This project uses the combination of a spectroscopic detector and a monochromator to produce scatter free images for use in breast imaging.

Reducing scatter is vital in mammography, where typical structures have either low contrast or small dimensions. The typical method to reduce scatter is the anti-scatter grid, which has the drawback of absorbing a fraction of the primary beam as well as scattered radiation. An increase in the dose is then required in order to compensate.

Compton-scattered X-rays have lower energy than the primary beam. When using a monochromatic beam and a spectroscopic detector the scattered beam will appear at a lower energy than the main beam in the detected spectrum. Therefore the scattered component can be windowed out of the spectrum, essentially producing a scatter free image if the detector is position sensitive.

The monochromator used in this study is made from a Highly Orientated Pyrolytic Graphite (HOPG) crystal with a mosaic spread of 0.4° ± 0.1°.

The detector is a pixellated spectroscopic detector that is made from a 2 cm x 2 cm x 0.1 cm CdTe crystal with a pixel pitch of 250 μm and an energy resolution of 0.8 keV at 59.9 keV.

This work presents the characterisation of the monochromator and initial imaging data.

9412-204, Session PSMon

Comparison of two CDMAM generations with respect to dose sensitivity

Johann Hummel, Marcus Kaar, Medizinische Univ. Wien (Austria); Marianne Floor, Roeland van der Burght, Artinis Medical Systems B.V. (Netherlands); Friedrich Semturs, Michael Figl, Medizinische Univ. Wien (Austria)

A contrast-detail phantom like the CDMAM phantom (Artinis Medical Systems, Zetten, NL) is suggested by the 'European protocol for the quality control of the physical and technical aspects of mammography screening' to evaluate image quality of digital mammography systems. In a recent paper the commonly used CDMAM 3.4 was evaluated according to its dose sensitivity in comparison to other phantoms. The successor phantom (CDMAM 4.0) features other disc diameters and thicknesses that were adapted to be more closely to the image quality which can be found in

modern mammography systems. It seems to be obvious to compare this two generations of phantoms with respect to a potential improvement.

The time-current product was varied within a range of clinically used values (40-160 mAs). Image evaluation was performed using the automatic evaluation software provided by Artinis. The relative dose sensitivity was compared in dependence of different diameters. Additionally, the IQFinv parameter, which averages over the diameters was computed to get a more global conclusion.

We found that the dose is of a considerable smoother dependence with the CMDAM 4.0 phantom. Also the IQFinv parameter shows a more linear behaviour than with the CDMAM 3.4. As the automatic evaluation shows different results on the two phantoms, conversion factors from automatic to human readouts have to be adapted consequently.

9412-205, Session PSMon

Dose and image quality measurements for contrast-enhanced dual energy mammography systems

Jennifer M. Oduko, The Royal Surrey County Hospital NHS Trust (United Kingdom); Peter Homolka, Medizinische Univ. Wien (Austria); Vivienne Jones, David Whitwam, Northampton General Hospital (United Kingdom)

The results of a patient dose survey of a contrast-enhanced dual energy mammography system are presented, showing mean glandular doses for both low and high energy components of the exposure. The distribution of doses is of an unusual pattern, very different from that normally measured in patient dose surveys. The contribution of the high energy component of the exposure to the total is shown to be about 20% of that of the low energy component. A phantom containing disks with a range of different iodine content was used, with tissue-equivalent materials, to investigate the properties of a dual energy system. The iodine signal difference to noise ratio is suggested as a measure of image quality. It was found to remain practically constant as phantom thickness was varied, and increased only slowly (with a power relationship) as air kerma increased. Other measurements showed good reproducibility of the iodine signal difference, and that it was proportional to iodine concentration in the phantom. The iodine signal difference was found to be practically the same for a wide range of phantom thickness and glandularity.

9412-206, Session PSMon

Method for inserting noise in digital mammography to simulate reduction in radiation dose

Lucas R. Borges, Helder C. R. Oliveira, Polyana F. Nunes, Marcelo A. C. Vieira, Univ. de São Paulo (Brazil)

The quality of clinical x-ray images is closely related to the radiation dose used in the imaging study. The general principle for selecting the radiation is ALARA ("as low as reasonably achievable"). The practical optimization, however, remains challenging. It is well known that reducing the radiation dose increases the quantum noise, which could compromise the image quality. In order to conduct studies about dose reduction in mammography, it would be necessary to acquire repeated clinical images, from the same patient, with different dose levels. This is, however, unethical due to radiation related risks. One solution is to simulate the effects of dose reduction in clinical images. This work proposes a new method, based on the Anscombe Transformation, which simulates dose reduction in digital mammography by inserting quantum noise into clinical mammograms acquired with the standard radiation dose. Thus, it is possible to simulate different levels of radiation doses without exposing the patient to new levels of radiation. The proposed method is capable of simulating images at different levels of radiation without repeated patient exposure. The achieved

quality of simulated images is the same as when using other methods found in the literature, with an advantage of lower computational cost, due to the use of the Anscombe Transformation instead of the Fourier Transformation.

9412-207, Session PSMon

Relationship between radiation dose and reduced X-ray sensitivity surrounding breast region using CR stimulable phosphor plate for mammography

Hiroko Nishide, Gifu Univ. of Medical Science (Japan) and Nagoya Univ. Graduate School of Medicine (Japan); Yoshie Kodera, Nagoya Univ. Graduate School of Medicine (Japan)

Computed radiography (CR) systems use a photostimulable phosphor plate (imaging plate ; IP) as a sensor for digital mammography. In clinical mammography, breast is almost exposed same region of IP, and therefor, direct x-ray regions surrounding suffer from reduced x-ray sensitivity. Consequently, the difference in x-ray sensitivity between the breast regions and the direct x-ray region was obtained. However, radiation dose quantity that reduces x-ray sensitivity is not known. In this study, we imaged a breast phantom under fixed conditions, and subsequently, we investigated the pixel value differences between the breast region and the direct x-ray regions. We measured the entrance air-kerma using a 110 sensing elements glass dosimeter, 22x5 lines, that were placed at the surface of the cassette including the IP. In order to measure the x-ray sensitivity, pre- and post-exposure breast phantom images were acquired over 200, 500, 1,000, 1,350, and 1,500 trials. The pixel values were measured at four points; in the breast region and in the direct x-ray region. The ratio of these pixel values were compared with the cumulative exposure dose. The ratio was nearly constant for 1,000 trials, but a significant reduction was observed after 1,350 trials. Further, in the image obtained after 1,500th trials, the shape of breast phantom could be observed. This image supports the fact that the x-ray sensitivity was lowered in the direct x-ray regions. The difference in the pixel value between the breast region and the direct x-ray region was obtained over 1,000 exposures at 100,000 mAs.

9412-208, Session PSMon

Physics of a novel magnetic resonance and electrical impedance combination for breast cancer diagnosis

Maria Kallergi, Technological Educational Institute of Athens (Greece); John J. Heine, H. Lee Moffitt Cancer Ctr. & Research Institute (United States); Ernest Wollin, Wollin Ventures, Inc. (United States)

PURPOSE: To present the physics of a novel combination of magnetic resonance mammography (MRM) and electrical impedance scanning (EIS) and its potential applications in breast cancer detection and diagnosis.

MATERIALS & METHODS: The electrical conductivity of breast tumors is a known clinical biomarker and could provide solutions to some of the limitations of MRM. The principle of the proposed magnetic resonance electrical impedance mammography (MREIM) is based on the addition of a time varying electric field during a standard MRM examination with an apparatus that is "invisible" to the patient. The theoretical analysis involves solving the magnetic field equations based on the tissue geometry in three-dimensional space.

RESULTS: Theory predicts two effects: (i) a shift effect along the read out gradient direction (frequency encode direction). (ii) An effect that occurs due to random phase adjustments acquired during each phase encoded signal before the read out gradient is applied. The random phasing alters the fundamental spatial response functions in both the read and phase-

encode directions. This random phase effect is more pronounced where the aberrational field is stronger.

CONCLUSIONS: The effective combination of MRM and EIS is possible without the use of fat suppression techniques, contrast agent injection as in dynamic contrast enhanced MRM, or reconstruction techniques and cumbersome positioning of electrodes on the breast surface as in MREITomography. The proposed MREIM induces a detectable differential signal at full image resolution in areas of higher electrical conductivity and could be done with standard MRM or in addition to procedures such as the DCEMRM.

9412-210, Session PSMon

Dual-energy (MV/kV) CT with probabilistic attenuation mapping for IGRT applications

Erik Pearson, The Univ. of Chicago (United States); Xiaochuan Pan, The Univ. of Chicago (United States); Charles A. Pelizzari, The Univ. of Chicago (United States)

Imaging plays an important role in the delivery of external beam radiation therapy. It is used to confirm the setup of the patient and to ensure accurate targeting and delivery of the therapeutic radiation dose. Most modern linear accelerators come equipped with a flat panel detector opposite the MV source as well as an independent kV imaging system, typically mounted perpendicular to the MV beam. kV imaging provides superior soft tissue contrast and is typically lower dose to the patient than MV imaging, however it can suffer from artifacts caused by metallic objects such as implants and immobilization devices. In addition to being less artifact prone, MV imaging also provides a direct measure of the attenuation for the MV beam which is useful for computing the therapeutic dose distributions. Furthermore either system requires a large angular coverage which is slow for large linear accelerators. We present a method for reconstructing tomographic images from data acquired at multiple x-ray beam energies using a statistical model of inherent physical properties of the imaged object. This approach can produce image quality superior to traditional techniques in the case of limited measurement data (angular sampling range, sampling density or truncated projections) and/or conditions in which the lower energy image would typically suffer from corrupting artifacts such as the presence of metals in the object. Both simulation and real data results are shown.

9412-211, Session PSMon

Interventional C-arm tomosynthesis for vascular imaging: initial results

David A. Langan, Bernhard E. H. Claus, Omar Al Assad, GE Global Research (United States); Yves L. Trousset, Cyril Riddell, Gregoire Avignon, GE Healthcare France (France); Stephen B. Solomon, Memorial Sloan Kettering Cancer Ctr. (United States); Hao Lai, Xin Wang, GE Global Research (United States)

As percutaneous vascular procedures address more complex disease states, there is an increasing need for intra-procedure 3D vascular imaging. In this paper, we investigate C-Arm 2-axis tomosynthesis ("tomo") as an alternative to C-Arm Cone Beam Computed Tomography (CBCT) for workflow situations in which the CBCT acquisition may be inconvenient or prohibited. We report on an experimental tomosynthesis acquisition implemented on a GE Healthcare Innova 4100 Angiographic Imaging System. During a tomo acquisition the tube and detector each orbit on a plane below and above the table respectively. The tomo orbit may be circular or elliptical, and the tomographic half-angle in our studies was varied from approximately 16 to 28 degrees as a function of orbit period. The trajectory, geometric calibration, and gantry performance are presented. We overview a multi-resolution iterative reconstruction employing compressed sensing techniques to mitigate artifacts associated with incomplete data reconstructions. In this work, we focus on the

reconstruction of small high contrast objects such as iodinated vasculature and interventional devices. We evaluate the overall performance of the acquisition and reconstruction through phantom acquisitions and a swine study. Both tomo and comparable CBCT acquisitions were performed during the swine study thereby enabling the use of CBCT as a reference in the evaluation of tomo vascular imaging. We close with a discussion of potential clinical applications for tomo, reflecting on the imaging and workflow results achieved.

9412-212, Session PSMon

Usefulness of an energy-binned photon-counting x-ray detector for dental panoramic radiograph

Tatsumasa Fukui, Akitoshi Katsumata, Asahi Univ. (Japan); Koichi Ogawa, Hosei Univ. (Japan); Shuu Fujiwara, Asahi Univ. (Japan)

Panoramic radiography is a commonly used imaging technique in dentistry.

A newly developed dental panoramic radiography system equips photon-counting type cadmium telluride (CdTe) semiconductor detector.

A possible usefulness of the x-ray energy analysis is to identify dental restorative (prosthetic) materials in the patient's teeth arch.

Results from this study suggested that x-ray energy scattergram analysis could be used to identify several dental materials in patient's panoramic radiograph.

In the clinical dentistry, it sometimes difficult to identify dental restorative materials by means of conventional visual and/or radiograph examinations.

Conference 9413: Image Processing

Tuesday - Thursday 24–26 February 2015

Part of Proceedings of SPIE Vol. 9413 Medical Imaging 2015: Image Processing

9413-1, Session 1

Highly accurate volumetry of the spinal cord

Florian Weiler, Fraunhofer MEVIS (Germany); Marita Daams, Vrije Univ. Medical Ctr. (Netherlands); Carsten Lukas, St. Josefs-Hospital, Ruhr-Univ. Bochum (Germany); Frederik Barkhof, Vrije Univ. Medical Ctr. (Netherlands); Horst K. Hahn, Fraunhofer MEVIS (Germany)

Quantitative analysis of the spinal cord from MR images is of significant clinical interest when studying certain neurologic diseases. Especially for multiple sclerosis, a number of studies have analyzed the relation between spinal cord atrophy and clinically monitored progression of the disease. A commonly analyzed parameter in this field is the mean cross-sectional area of the cord, which can also be expressed as the average volume per cm.

In this paper, we present a novel approach for precise measurement of the volume, length, and cross-sectional area of the spinal cord from T1-weighted MR images. It is computationally fast, with a low effort of required user interaction. It is based on a semi-automated pre-segmentation of a sub-section of the spinal cord, followed by an automated Gaussian mixture-model fit for volume calculation. Additionally, the centerline of the cord is extracted, which allows for calculation of the mean cross-sectional area of the measured section.

We evaluate the accuracy of our method with respect to scan/re-scan reproducibility as well as intra- and inter-rater agreement. We achieved a mean coefficient of variation of 0.62% over repeated MR acquisitions, mean CoV of 0.39% for intra-rater comparison, and a mean CoV of 0.28% for intra-rater comparison by five different observers. These results prove a high sensitivity to detect even small changes in atrophy, as it could typically be observed over the temporal progression of MS.

9413-2, Session 1

Constructing a statistical atlas of the radii of the optic nerve and cerebrospinal fluid sheath in young healthy adults

Robert L. Harrigan, Andrew J. Plassard, Louise A. Mawn, Robert L. Galloway, Seth A. Smith, Bennett A. Landman, Vanderbilt Univ. (United States)

Optic neuritis is a sudden inflammation of the optic nerve (ON) and is marked by pain on eye movement, and visual symptoms such as a decrease in visual acuity, color vision, contrast and visual field defects. The ON is closely linked with multiple sclerosis (MS) and patients have a 50% chance of developing MS within 15 years. Recent advances in multi-atlas segmentation methods have omitted volumetric assessment of the ON. Current state of the art for measuring the size of the ON has been done by hand. We utilize a new method of automatically segmenting the ON to measure the radii of both the ON and surrounding cerebrospinal fluid (CSF) to develop a normative distribution of healthy young adults. We examine this distribution for any trends and find that ON and surrounding CSF radii do not vary significantly between 20-35 years of age and between sexes. We evaluate how six patients with a history of remote optic neuritis compare to this distribution of healthy controls. Of these six patients, five qualitatively have areas that differ from the distribution of healthy controls from the globe to the chiasm which suggests this technique could be used to distinguish between normal and abnormal optic nerves across patient cohorts. .

9413-3, Session 1

Adaptive sampling of CT data for myocardial blood flow estimation from dose-reduced dynamic CT

Dimple Modgil, The Univ. of Chicago Medical Ctr. (United States); Michael D. Bindschadler, Adam M. Alessio, Univ. of Washington (United States); Patrick J. La Rivière, The Univ. of Chicago Medical Ctr. (United States)

Quantification of myocardial blood flow (MBF) can aid in the diagnosis and treatment of coronary artery disease (CAD). However, there are no widely accepted clinical methods for evaluating MBF. Dynamic CT holds the promise of providing a quick and easy method to measure MBF quantitatively, but it comes at the cost of a large radiation dose to the patient. In our previous work, we explored techniques to reduce the patient dose by either reducing the tube current or by uniformly reducing the number of temporal frames in the dynamic CT sequence. These dose reduction techniques result in very noisy data, which can give rise to large errors in MBF estimation. In this work, we try to minimize the dose and obtain the most accurate MBF estimate through addressing the following questions: when in the time attenuation curve (TAC) should the CT data be collected and at what tube current(s). We hypothesize that increasing the sampling rate and/or tube current during the timeframe when the myocardial CT number is most sensitive to the flow rate, while reducing them elsewhere, can achieve better estimation accuracy at reduced dose. We perform simulations of contrast agent kinetics and CT acquisitions to evaluate the relative MBF estimation performance of several clinically viable adaptive acquisition methods. We found that adaptive temporal and tube current sequences can be performed that impart an effective dose of less than 6 mSv and allow for reductions in MBF estimation RMSE on the order of 4% or more compared to uniform acquisition sequences with comparable or higher radiation doses.

9413-4, Session 1

Segmentation of vascular structures and hematopoietic cells in 3D microscopy images and quantitative analysis

Jian Mu, Danny Ziyi Chen, Lin Yang, Univ. of Notre Dame (United States); Malgorzata M. Kamocka, Nadia Carlesso, Amy L. Zollman, Indiana Univ. School of Medicine (United States)

In this paper, we present image processing methods for quantitative study of how the bone marrow

icroenvironment changes (characterized by altered vascular structure and hematopoietic cell distribution) when the Notch signaling pathway is deleted. To capture such structural changes and study how the changes correlate with the deletion of Notch pathway, we develop algorithms that automatically segment vascular structures and hematopoietic cells in 3D microscopy images, perform quantitative analysis of the properties of the segmented vascular structures and cells, and examine how such properties change. In processing images, we apply local thresholding to segment vessels, and add post-processing steps to deal with imaging artifacts. We propose an improved watershed algorithm that relies on both intensity and shape information and can separate multiple overlapping cells better than traditional watershed methods. We then quantitatively compute various features of the vascular structures and hematopoietic cells, such as the branches and size of vessels and the distribution of cells. In analyzing vascular properties, we give algorithms for pruning fake vessel segments and branches based on vessel skeletons. Our algorithms can segment vascular structures and hematopoietic cells with good quality.

The quantitative analysis reveals property changes in samples with deleted Notch pathway, and is a useful tool for biologists to quantitatively study changes in the bone marrow microenvironment, for developing possible therapeutic strategies to help the bone marrow microenvironment recovery.

9413-5, Session 1

Fast left ventricle tracking in CMR images using localized anatomical affine optical flow

Sandro Queirós, ICVS/3B's - PT Government Associate Lab., School of Health Sciences, Univ. do Minho (Portugal) and Lab. on Cardiovascular Imaging and Dynamics, Katholieke Univ. Leuven (Belgium); João L. Vilaça, ICVS/3B's - PT Government Associate Lab., School of Health Sciences, Univ. do Minho (Portugal) and DIGARC – Polytechnic Institute of Cávado and Ave (Portugal); Pedro Morais, ICVS/3B's - PT Government Associate Lab., School of Health Sciences, Univ. do Minho (Portugal); Jaime C. Fonseca, Univ. do Minho (Portugal); Jan D'hooge, Lab. on Cardiovascular Imaging and Dynamics, KU Leuven (Belgium); Daniel Barbosa, ICVS/3B's - PT Government Associate Lab., School of Health Sciences, Univ. do Minho (Portugal) and DIGARC – Polytechnic Institute of Cávado and Ave (Portugal)

Background: In daily cardiology practice, left ventricular (LV) global function assessment using non-invasive imaging remains central for the diagnosis and follow-up of patients with cardiovascular diseases. Despite the several methodologies currently available for LV segmentation in cardiac magnetic resonance (CMR) images, a fast and complete LV delineation is still limitedly available for routine use.

Purpose: In this study, a localized anatomically constrained affine optical flow method is proposed for fast and automatic LV tracking throughout the full cardiac cycle in short-axis CMR images.

Materials and Method: Starting from an automatically delineated LV in the end-diastolic frame, the endocardial and epicardial boundaries are propagated by estimating the motion between adjacent cardiac phases using optical flow. In order to reduce the computational burden, the motion is only estimated in an anatomical region of interest around the tracked boundaries and subsequently integrated into a local affine motion model. Such localized estimation enables to capture complex motion patterns, while still being spatially consistent. The method was validated on 45 CMR datasets taken from the 2009 MICCAI LV segmentation challenge.

Results: The proposed approach proved to be robust and efficient, with an average error of 2.1mm and a correlation with reference ejection fraction of 0.98 (1.9±4.5%). Moreover, it showed to be fast, taking 5 seconds for the tracking of a full 4D dataset (30ms per image).

Conclusion: A novel fast, robust and accurate LV tracking methodology was proposed, enabling accurate assessment of relevant global function cardiac indices, such as volumes and ejection fraction.

9413-6, Session 2

The open microscopy environment: open image informatics for the life and biomedical sciences *(Keynote Presentation)*

Jason Swedlow, Univ. of Dundee (United Kingdom)

Despite significant advances in biological imaging and analysis, major informatics challenges remain unsolved: file formats are proprietary, storage and analysis facilities are lacking, as are standards for sharing image data and results. The Open Microscopy Environment (OME) [1] is an open-source software framework developed to address these challenges. OME has three components—an open data model for biological imaging: OME data model; standardized file formats (OME-TIFF) and software libraries for file conversion (Bio-Formats [2]); and a software platform for image data management and analysis (OMERO [3]).

The Java-based OMERO client-server platform [3] comprises an image metadata store, an image repository, visualization and analysis by remote access, enabling sharing and publishing of image data. OMERO's model-based architecture has enabled its extension into a range of imaging domains, including light and electron microscopy, high content screening and recently into applications using non-image data from clinical and genomic studies [4].

Our current version, OMERO-5 improves support for large datasets and reads images directly from their original file format, allowing access by third party software. OMERO and Bio-Formats run the JCB DataViewer [5], the world's first on-line scientific image publishing system and several other institutional image data repositories (e.g. [6], [7]).

[1] http://openmicroscopy.org

[2] http://openmicroscopy.org/site/products/bio-formats

[3] http://openmicroscopy.org/site/products/omero

[4] http://www.openmicroscopy.org/site/products/partner

[5] http://jcb-dataviewer.rupress.org/

[6] http://odr.stowers.org

[7] http://emdatabank.org/

9413-7, Session 2

Tractography of the optic radiation with diffusion compartment imaging and multi-fascicle modeling

Jolene Singh, Boston Children's Hospital (United States); Rory J. Piper, College of Medicine and Veterinary Medicine, The Univ. of Edinburgh (United Kingdom); Vinay Jayaram, Boston Children's Hospital (United States); Benoit Scherrer, Maxime Taquet, Onur Afacan, Boston Children's Hospital (United States) and Harvard Medical School (United States); Sean Clancy, Boston Children's Hospital (United States); Simon K. Warfield, Boston Children's Hospital (United States) and Harvard Medical School (United States)

Temporal lobe resection is a potentially curative intervention for temporal lobe epilepsy (TLE). Visual field defects may arise if a resection transects the optic radiation. The anatomic course of the optic radiation is known to have substantial inter-individual variability. Noninvasive localization of the precise course of the visual pathways in individual patients offers the possibility of improved assessments of the risks and benefits of a temporal lobe resection.

Diffusion weighted imaging is an excellent tool for localization of critical white matter pathways. However, methodological differences in acquisition protocols and modeling choices have led to substantial variation in the localization of the vision pathways, and the optimal approach for characterization of the optic radiation including Meyer's loop is unclear.

Here, we show the impact of high spatial resolution diffusion compartment imaging combined with either conventional single tensor diffusion modeling (DTI) or multi-fascicle modeling (MFM). In addition, we include a novel smoothing filter for multi-fascicle modeling which helps to resolve tensors in regions of fiber crossings. We conclude that spatial resolution, diffusion compartment imaging, choice of diffusion model, regularization constraint and use of super resolution reconstruction (SRR) imaging are all necessary to conduct optimal and clinically feasible imaging of the OpR in preparation for tractography as part of presurgical planning for anterior temporal lobe resection.

9413-8, Session 2

7T multi-shell hybrid diffusion imaging (HYDI) for mapping brain connectivity in mice

Madelaine Daianu, Neda Jahanshad, Julio E. Villalon-Reina, Gautam Prasad, The Univ. of Southern California (United States); Russell E. Jacobs, Samuel Barnes, California Institute of Technology (United States); Berislav V. Zlokovic, Axel Montagne, Paul M. Thompson, The Univ. of Southern California (United States)

Diffusion weighted imaging (DWI) is widely used to study microstructural characteristics of the brain. High angular resolution diffusion imaging (HARDI) samples diffusivity at a large number of spherical angles, to better resolve neural fibers that mix or cross. Here, we implemented a framework for advanced mathematical analysis of mouse 5-shell HARDI (b=1000, 3000, 4000, 8000, 12000 s/mm2), also known as hybrid diffusion imaging (HYDI). Using q-ball imaging (QBI) at ultra-high field strength (7 Tesla), we computed diffusion and fiber orientation distribution functions (dODF, fODF) to better detect crossing fibers. We also computed a quantitative anisotropy (QA) index, and deterministic tractography, from the peak orientation of the fODFs. We found that the signal to noise ratio (SNR) of the QA was significantly higher in single and multi-shell reconstructed data at the lower b-values (b=1000, 3000, 4000 s/mm2) than at higher b-values (b=8000, 12000 s/mm2); the b=1000 s/mm2 shell increased the SNR of the QA in all multi-shell reconstructions, but when used alone or in <5 multi-shell data, it led to higher angular error for reconstructing the major fibers, compared to 5-shell HYDI. Multi-shell data reconstructed major fibers with less error than single-shell data, and was most successful at reducing the angular error when the lowest shell was excluded (b=1000 s/mm2). Overall, high-resolution connectivity mapping with 7T HYDI offers great potential for understanding unresolved changes in mouse models of brain disease.

9413-9, Session 2

Measuring the lesion load of multiple sclerosis patients within the corticospinal tract

Jan Klein, Fraunhofer MEVIS (Germany); Katrin Hanken, Klinikum Bremen-Ost (Germany); Jasna Koceva, Fraunhofer MEVIS (Germany); Helmut Hildebrandt, Klinikum Bremen-Ost (Germany) and Institut für Psychologie, Carl von Ossietzky Univ. Oldenburg (Germany); Horst K. Hahn, Fraunhofer MEVIS (Germany)

In this paper we present a framework for reliable determination of the lesion load within the corticospinal tract (CST) of multiple sclerosis patients. The basis constitutes a probabilistic fiber tracking approach which checks possible parameter intervals on the fly using an ana-tomical brain atlas. By exploiting the range of those intervals, the algorithm is able to resolve fiber crossings and to determine the CST in its full entity although it can use a simple diffusion tensor model. Another advantage is its short running time, tracking the CST takes less than a minute. For segmenting the lesions we developed a semi-automatic approach. First, a trained classifier is applied to multimodal MRI data (T1/FLAIR) where the spectrum of lesions has been determined in advance by a clustering algorithm. This leads to an automat-ic detection of the lesions which can be manually corrected afterwards using a threshold-based approach.

For evaluation we scanned 46 MS patients and 16 healthy controls. Fiber tracking has been performed using our novel fiber tracking and a standard deflection based algorithm. The results show that the lesion load in the CST correlates much better with the motor status if using our new approach. Furthermore, a correlation with the duration needed for diagnosis (from first symptoms to diagnosis) and with the duration of the disease can be shown.

Additionally, a low correlation between old and new approach supports the observation that standard DTI fiber tracking is not able to track and quantify the CST reliably.

9413-10, Session 3

Joint multi-shot multi-channel image reconstruction in compressive diffusion weighted MR imaging

Hao Zhang, Yunmei Chen, Univ. of Florida (United States); Feng Huang, Philips Research (China); Eduardo Pasiliao Jr., Air Force Research Lab. (United States)

Multi-Shot Echo-Planar Imaging (msEPI) based Diffusion Weighted Imaging (DWI) has the potential to provide higher spatial resolution results compared with the generally used Single-Shot EPI method. Nevertheless, there are motion-induced phase errors among images reconstructed from different shots. To address this issue, we assume that the images are similar to each other among all shots except for some error. In another word, if we store vectorized images into one matrix as columns, we could separate this matrix into two new matrices with one of them having low column rank representing desired image and the other is sparse which accounting for motion-induced error. We proposed a convex optimization problem based on this assumption which consists of a Sensitivity Encoding (SENSE) based data fidelity term, a Total Variation(TV) regularization and a low-rank and sparse matrix decomposition of images from all shots. We then solve the model by an accelerated Alternating Direction Method of Multipliers (AADMM) scheme. Our preliminary results on 6 and 8 shots EPI reconstruction show that motion induced artifact are removed completely.

9413-11, Session 3

Multi-contrast magnetic resonance image reconstruction

Meng Liu, Yunmei Chen, Hao Zhang, Univ. of Florida (United States); Feng Huang, Philips Healthcare (Suzhou) Co. Ltd. (China)

In clinical exams, multi-contrast images from conventional MRI are scanned with the same field of view (FOV) for complementary diagnostic information, such as proton density- (PD-), T1- and T2-weighted images. Their sharable information can be utilized for more robust and accurate image reconstruction. In this work, we propose a novel model and an efficient algorithm for joint image reconstruction and coil sensitivity estimation in multi-contrast partially parallel imaging (PPI) in MRI.

Our algorithm restores the multi-contrast images by minimizing an energy function consisting of an L2-norm fidelity term to reduce construction errors caused by motion, a regularization term of underlying images to preserve common anatomical features by using vectorial total variation (VTV) regularizer, and updating sensitivity maps by Tikhonov smoothness based on their physical property.

We present the numerical results including T1- and T2-weighted MR images recovered from partially scanned k-space data and provide the comparisons between our results and those obtained from the related existing works. Our numerical results indicate that the proposed method using vectorial TV and penalties on sensitivities can be made promising and widely used for multi-contrast multi-channel MR image reconstruction.

SPIE. MEDICAL IMAGING

9413-12, Session 3

Image-based compensation for involuntary motion in weight-bearing C-arm CT scanning of knees

Mathias Unberath, Friedrich-Alexander-Univ. Erlangen-Nürnberg (Germany); Jang-Hwan Choi, Stanford Univ. (United States); Martin Berger, Andreas K. Maier, Friedrich-Alexander-Univ. Erlangen-Nürnberg (Germany); Rebecca Fahrig, Stanford Univ. (United States)

We previously introduced four fiducial marker-based strategies to compensate for involuntary knee-joint motion during weight-bearing C-arm CT scanning of the lower body. 2D methods showed significant reduction of motion-related artifacts, but 3D methods worked best.

However, previous methods led to increased examination times and patient discomfort caused by the marker attachment process. Moreover, sub-optimal marker placement may lead to decreased marker detectability and therefore unstable motion estimates. In order to reduce overall patient discomfort, we developed a new image-based 2D projection shifting method.

A C-arm cone-beam CT system was used to acquire projection images of five healthy volunteers at various flexion angles. Projection matrices for the horizontal scanning trajectory were calibrated using the Siemens standard PDS-2 phantom. The initial reconstruction was forward projected using maximum-intensity projections (MIP), yielding an estimate of a static scan. This estimate was then used to obtain the 2D projection shifts via registration.

For the scan with the most motion, the proposed method reproduced the marker-based results with a mean error of 2.90 mm +/- 1.43 mm (compared to a mean error of 4.10 mm +/- 3.03 mm in the uncorrected case). Bone contour contrast as well as the continuity of the surrounding modeling clay layer was improved. The proposed method is a first step towards automatic image-based, marker-free motion-compensation.

9413-13, Session 3

Super-resolution for medical image corrupted by heavy noise

Dai Viet Tran, Marie Luong, Li-Thao-Té Sébastien, Jean-Marie Rocchisani, Françoise Dibos, Univ. Paris 13 (France); Thuong Le-Tien, Vietnam National Univ. (Viet Nam)

Medical images often suffer from noise and low-resolution, which may compromise the accuracy of diagnosis. How to improve the image resolution in case of heavy noise is still a challenging issue. This paper introduces a novel Example-based Super-resolution (SR) method for medical images corrupted by heavy Poisson noise, by integrating efficiently denoising and SR in the same framework. The purpose of the problem is to estimate a high-resolution (HR) image from a single noisy low-resolution (LR) image, with the help of a given set of standard images which are used as examples. Precisely, for each given noisy LR patch, the idea is to find its nearest neighbor patches from the training set and to estimate its HR version by computing a regression function based on the construction of a reproducing kernel Hilbert space from the set of its nearest neighbors. To obtain the corresponding set of the k-nearest neighbour in the training set, a coarse search using the shortest Euclidean distance is first performed, followed by a refine search using a criterion based on the distribution of Poisson noise and the Anscombe transformation. This paper also evaluates the performance of the method comparing to other state-of-the-art denoising methods and SR methods. The obtained results demonstrate its efficiency, especially for heavy Poisson noise.

9413-14, Session 3

Spline-based sparse tomographic reconstruction with Besov priors

Elham Sakhaee, Alireza Entezari, Univ. of Florida (United States)

Tomographic reconstruction from limited X-ray data is an ill-posed inverse problem.

A common approach, based on the Bayesian framework, is to search for the maximum a posteriori (MAP) estimate of the image unknowns using a likelihood term and prior knowledge.

We present a spline framework for sparse tomographic reconstruction that leverages higher-order basis functions for image discretization while incorporating image priors for the MAP estimate.

Recent results on the Bayesian inversion have shown the advantages of Besov priors for the convergence of the estimates as the image discretization is refined.

We integrate the Besov space priors in the spline tomography framework where utilizing B-splines, as higher-order basis functions for image discretization, are shown to improve accuracy compared to the standard, first-order, pixel-basis.

Our experiments show that the synergy produced from higher-order basis functions for image discretization together with the discretization-invariant Besov priors leads to significant improvements in tomographic reconstruction. The advantages of the proposed Bayesian inversion framework are examined for image reconstruction from limited number of projections in a few-view setting.

9413-15, Session 4

Rank-sparsity constrained atlas construction and phenotyping

Darin P. Clark, Cristian T. Badea, Duke Univ. Medical Ctr. (United States) and Ctr. for In Vivo Microscopy (United States)

Atlas construction is of great interest in the medical imaging community as a tool to visually and quantitatively characterize anatomic variability within a population. Because such atlases generally exhibit superior data fidelity relative to the individual data sets from which they are constructed, they have also proven invaluable in numerous informatics applications such as automated segmentation and classification, regularization of individual-specific reconstructions from undersampled data, and for extracting physiologically relevant functional metrics. Perhaps the most valuable role of an anatomic atlas is not to define what is "normal," but, in fact, to recognize what is abnormal. Here we propose and demonstrate a novel anatomic atlas construction strategy which simultaneously recovers the average anatomy and the deviation from average in a visually meaningful way. The proposed approach treats the problem of atlas construction within the context of robust principal component analysis (RPCA) in which the redundant portion of the data (i.e. the low rank atlas) is separated from the spatially and gradient sparse portion of the data unique to each individual (i.e. the sparse variation). In this abstract, we demonstrate the application of RPCA decomposition to the Shepp-Logan phantom including several forms of variability encountered with in vivo data: population variability, class variability, contrast variability, and individual variability. We then present preliminary results produced by applying the proposed approach to in vivo, murine cardiac micro-CT data acquired in a model of right ventricle hypertrophy induced by pulmonary arteriole hypertension.

9413-16, Session 4

Compressed sensing MRI using higher order multi-scale FREBAS for sparsifying transform function

Satoshi Ito, Utsunomiya Univ. (Japan); Kenji Ito, Utsunomiya Univeristy (Japan) and Utsunomiya Univ. (Japan); Mone Shibuya, Yoshifumi Yamada, Utsunomiya Univeristy (Japan)

Reduction of acquisition time is a major issue in magnetic resonance (MR) imaging. Compressed sensing (CS), a recently proposed theory for MR image reconstruction, states that a sparsely represented signal can be reconstructed from many fewer measurements than were previously suggested by the conventional Nyquist sampling theory.

Successful reconstruction from an undersampled MR signal using CS requires satisfaction of 2 criteria?incoherency between the sampling matrix and the basis of the sparsifying transformation function and the sparsity introduced by that function. The quality of the reconstructed images depends strongly on the sparsifying transform, and in most CS-MRI studies, the discrete cosine transform or the wavelet transform has been used for sparsification.

Although the wavelet transform offers good sparsity in the transformed domain, it can yield less detail by failing to recover edges and curves [3,4], so a more effective sparsifying transform is needed. In the present paper, the use of the Fresnel domain band split transformation (FREBAS) is proposed for sparsification during CS-MRI reconstruction. This transform involves two different Fresnel transformation algorithms, and allows highly directional multi-resolution image decomposition that yields superior reconstructed images. The FREBAS algorithm, which consists of three fast Fourier transforms and three quadratic phase modulations, is easier to calculate than the wavelet transform, and can therefore be more easily implemented in the CS procedure. We have shown that the alternation of the scaling parameter used in the FREBAS transform can improve the incoherence between the sampling matrix and the basis of the sparsifying transform and therefore allow higher PSNR of reconstructed images compared to single-step FREBAS transform domain thresholding. The FREBAS transform allows the choice of an optional scaling parameter during image decomposition while wavelet transform or curvelet transform have the restriction that spatial frequency must be divided into the power of 2 sub-bands. In the present study, to further improve the incoherence between the sampling matrix and the basis of the sparsifying transform, successive thresholding in FREBAS transform domain using the higher feasibility in the choice of FREBAS scaling parameter, i.e. multi-scale FREBAS transform domain thresholding using 6 kind or more scaling parameters were used in the FREBAS transformed domain.

Successive application of the FREBAS transform was found to strongly increase the incoherence between the sampling matrix and the basis of the sparsifying transform, which allowed extraction of excellent images with fewer artifacts, without the need for any special training or knowledge of MR imaging data. The proposed method is insensitive to the sampling trajectory of the signal and produces good-quality images, particularly at low sampling rates

9413-17, Session 4

Intraparenchymal hemorrhage segmentation from clinical head CT of patients with traumatic brain injury

Snehashis Roy, Henry M. Jackson Foundation (United States); Sean Wilkes, Ramon Diaz-Arrastia, Uniformed Services Univ. of the Health Sciences (United States); John A. Butman, National Institutes of Health (United States); Dzung L. Pham, Henry M. Jackson Foundation (United States)

Quantification of hemorrhages in head computed tomography (CT) images from patients with traumatic brain injury (TBI) has potential applications in monitoring disease progression, treatment planning, and for better understanding the pathophysiology of TBI. Although manual segmentations can provide accurate measures of hemorrhages, the processing time and inter-rater variability make it infeasible for large studies. In this paper, we propose a fully automatic novel pipeline for segmenting intraparenchymal hemorrhages (IPH) from clinical head CT images. Unlike previous methods of model based segmentation or active contour techniques, we rely on relevant and matching examples from already segmented images by trained raters. First, the CT images are skull-stripped. Second, example patches from an "atlas" CT and its manual segmentation are used to learn a two-class sparse dictionary for hemorrhage and normal tissue. Then, for a different "subject" CT, a subject patch is modeled as sparse convex combination of a few atlas patches from the dictionary. The same convex combination is applied to the atlas segmentation patches to generate a membership for the hemorrhages at each voxel. Hemorrhages are segmented from 25 subjects with various degrees of TBI. Results are compared with segmentations obtained from an expert rater. A median Dice coefficient of 0.85 between automated and manual segmentations are achieved. A linear fit between automated and manual volumes show a slope of 1.0047, indicating no consistent bias between them.

9413-18, Session 4

Alternating minimization algorithm with iteratively reweighted quadratic penalties for compressive transmission tomography

Yan Kaganovsky, Shaobo Han, Duke Univ. (United States); Soysal Degirmenci, Washington Univ. in St. Louis (United States); Ikenna Odinaka, Andrew D. Holmgren, Duke Univ. (United States); David G. Politte, Joseph A. O'Sullivan, Washington Univ. in St. Louis (United States); Lawrence Carin, Duke Univ. (United States)

We propose an alternating minimization (AM) algorithm for estimating the attenuation functions in transmission x-ray tomography using sparsity-promoting priors. As opposed to the standard maximum-a-posteriori (MAP) solution, we use the automatic relevance determination (ARD) framework. In the ARD approach, the sparsity (or compressibility) of the imaged object is promoted by introducing latent variables which serve as weights to a quadratic penalty, with one weight for each pixel/voxel, and are learned from the data. In addition to the usual object estimate, ARD also provides measures of uncertainty (variances) about the estimated value, and circumvents the need for tuning nuisance parameters that determine the trade-off between the data fidelity and the prior. We extend ARD to Poisson noise models and interpret it as a reweighted L2 (quadratic) penalty algorithm. Importantly, this reweighting scheme effectively promotes sparsity of the gradient magnitude (similarly to TV). As opposed to prior reweighted L2 algorithms, we provide a principled way to determine the reweighting. The AM-ARD algorithm iterates between two steps: (1) minimize a smooth function with respect to the posterior mean and variance, (2) compute the weights of the quadratic penalty for each pixel/voxel in closed form. We apply the convex decomposition lemma in a novel way and derive a separable surrogate function that leads to a parallel algorithm. Interestingly, the computation of the mean and variance can be done in parallel within each iteration. We report the acceleration of the proposed algorithm using ordered subsets.

9413-19, Session 5

Revealing latent value of clinically acquired CTs of traumatic brain injury through multi-atlas segmentation in a retrospective study of 2,219 subjects

Andrew J. Plassard, Patrick D. Kelly, Andrew J. Asman, Hakmook Kang, Mayur B. Patel, Bennett A. Landman, Vanderbilt Univ. (United States)

Medical imaging plays a key role in guiding treatment of traumatic brain injury (TBI) and for diagnosing intracranial hemorrhage; most commonly rapid computed tomography (CT) imaging is performed. Outcomes for patients with TBI are variable and difficult to predict upon hospital admission. Quantitative outcome scales (e.g., the Marshall classification) have been proposed to grade TBI severity on CT, but such measures have had relatively low value in staging patients by prognosis. Herein, we examine a cohort of 2,219 subjects admitted for TBI and imaged clinically to identify potential prognostic metrics using a "big data" paradigm. For all patients, a brain scan was segmented with multi-atlas labeling, and intensity/volume/texture features were computed in a localized manner. In a 10-fold cross-validation experiment of 1,003 subjects, the explanatory value of the image-derived features is assessed for length of hospital stay (days), discharge disposition (five point scale from death to return home), and the Rancho Los Amigos functional outcome score (Rancho Score). Image-derived features increased the predictive R2 to 0.38 (from 0.18) for length of stay, to 0.51 (from 0.4) for discharge disposition, and to 0.31 (from 0.16) for Rancho Score (over models consisting only of non-imaging admission metrics, but including positive/negative radiological CT findings). This study demonstrates that high volume retrospective analysis of clinical imaging data can reveal imaging signatures with prognostic value. These features were then validated on a cohort of 1,219 withheld from the initial analysis. The image-derived features showed provided an R2 of .50 for discharge disposition, .40 for length of stay, and .22 for Rancho Score. Moreover, the increase in prognostic value would improve staging for intervention assessment and provide more reliable guidance for patients.

9413-20, Session 5

Efficient abdominal segmentation on clinically acquired CT with SIMPLE context learning

Zhoubing Xu, Ryan P. Burke, Christopher P. Lee, Rebeccah B. Baucom, Benjamin K. Poulose, Richard G. Abramson, Bennett A. Landman, Vanderbilt Univ. (United States)

Abdominal segmentation on clinically acquired computed tomography (CT) has been a challenging problem given the inter-subject variance of human abdomens and complex 3-D relationships among organs. Multi-atlas segmentation (MAS) provides a potentially robust solution by leveraging label atlases via image registration and statistical fusion. We posit that the efficiency of atlas selection requires further exploration in the context of substantial registration errors. The selective and iterative method for performance level estimation (SIMPLE) method is a MAS technique integrating atlas selection and label fusion that has proven effective for prostate radiotherapy planning. Herein, we revisit atlas selection and fusion techniques for segmenting 12 abdominal structures using clinically acquired CT. Using a re-derived SIMPLE algorithm, we show that performance on multi-organ classification can be improved by accounting for exogenous information through Bayesian priors (so called context learning). These innovations are integrated with the joint label fusion (JLF) approach to reduce the impact of correlated errors among selected atlases for each organ, and a graph cut technique is used to regularize the combined segmentation. In a study of 100 subjects, the proposed method outperformed other comparable MAS approaches, including majority vote, SIMPLE, JLF, and the Wolz locally weighted vote technique. The

proposed technique provides consistent improvement over state-of-the-art approaches (median improvement of 7.0% and 16.2% in DSC over JLF and Wolz, respectively) and moves toward efficient segmentation of large-scale clinically acquired CT data for biomarker screening, surgical navigation, and data mining.

9413-21, Session 5

Longitudinal graph-based segmentation of macular OCT using fundus alignment

Andrew Lang, Aaron Carass, Omar Al-Louzi, Pavan Bhargava, Howard S. Ying, Peter A. Calabresi, Jerry L. Prince, Johns Hopkins Univ. (United States)

Segmentation of retinal layers in optical coherence tomography (OCT) has become an important diagnostic tool for a variety of ocular and neurological diseases. Currently, all OCT segmentation algorithms analyze data independently, ignoring previous scans, which can lead to spurious measurements due to algorithm variability and failure to identify subtle changes in retinal layers. In this paper, we present a graph-based segmentation framework to provide consistent longitudinal segmentation results. Regularization over time is accomplished by adding weighted edges between corresponding voxels at each visit. We align the scans to a common subject space before connecting the graphs by registering the data using both the retinal vasculature and retinal thickness generated from a low resolution segmentation. This initial segmentation also allows the higher dimensional temporal problem to be solved more efficiently by reducing the graph size. Validation is performed on longitudinal data from 24 subjects where we explore the variability between our longitudinal graph method and a cross-sectional graph analysis. Our results demonstrate that the longitudinal component improves segmentation consistency, particularly in areas where the boundaries are difficult to visualize due to poor scan quality.

9413-22, Session 5

Machine learning for the automatic localisation of foetal body parts in cine-MRI scans

Chris J. Bowles, Niamh Nowlan, Imperial College London (United Kingdom); Tayyib T. A. Hayat, Christina Malamateniou, King's College London (United Kingdom); Mary A. Rutherford, Imperial College London (United Kingdom); Joseph V. Hajnal, King's College London (United Kingdom); Daniel Rueckert, Bernhard Kainz, Imperial College London (United Kingdom)

Being able to automatically locate individual foetal body parts has the potential to dramatically reduce the time taken to process time resolved foetal Magnetic Resonance Imaging (cine-MRI) scans, for example, for use in automatic evaluation of foetal development. Currently, manual preprocessing of every scan is required to locate body parts before analysis can be performed. With the volume of scans becoming available set to increase as cine-MRI scans become more prevalent in clinical practice, this stage of manual preprocessing may soon become a bottleneck, limiting the speed of advances in this area. Any tools which can automate this process will therefore save many hours of research time and increase the rate of discoveries in what is a key area in understanding early human development.

Our proposed method uses Fourier transforms to suppress the periodic effects of maternal breathing and to locate the position of the foetus in the scan. The scan is next split into shorter periods of foetal activity. The locations of potential body parts in each period are then identified by performing clustering on motion vector fields derived from foetal movement using optical flow, effectively locating areas which consistently move at the same time and in the same direction. These areas are then extracted and

classified probabilistically as either head, body, arm, leg or maternal tissue. Finally, the probabilities from each identified region are

temporally propagated and combined, to give a final estimate for the location of each body part.

9413-23, Session 5

MS lesion segmentation using a multi-channel patch-based approach with spatial consistency

Roey Mechrez, Tel Aviv Univ. (Israel); Jacob Goldberger, Bar-Ilan Univ. (Israel); Hayit Greenspan, Tel Aviv Univ. (Israel)

This paper presents an automatic method for segmentation of Multiple Sclerosis (MS) in Magnetic Resonance Images (MRI) of the brain. The approach is based on similarities between multi-channel patches (T1, T2 and FLAIR). An MS lesion patch database is built using training images for which the label maps are known. For each patch in the testing image, k similar patches are retrieved from the database. The matching labels for these k patches are then combined to produce an initial segmentation map for the test case. Finally a novel iterative patch-based label refinement process based on the initial segmentation map is performed to ensure spatial consistency of the detected lesions. A leave-one-out evaluation is done for each testing image in the MS lesion segmentation challenge of MICCAI 2008. Results are shown to compete with the state-of-the-art methods on the MICCAI 2008 challenge.

9413-24, Session 6

Automatic sulcal curve extraction on the human cortical surface

Ilwoo Lyu, Sun Hyung Kim, Martin A. Styner, The Univ. of North Carolina at Chapel Hill (United States)

The recognition of sulcal regions on the cortical surface is an important task to shape analysis and landmark detection. However, it is challenging especially in a complex, rough human cortex. In this paper, we focus on the extraction of sulcal curves from the human cortical surface. The previous sulcal extraction methods are time-consuming in practice and often have a difficulty to delineate curves correctly along the sulcal regions in the presence of significant noise. Our pipeline is summarized in two main steps: 1) We extract candidate sulcal points spread over the sulcal regions. We further reduce the size of the candidate points by applying a line simplification method. 2) Since the candidate points are potentially located away from the exact valley regions, we propose a novel approach to connect candidate sulcal points so as to obtain a set of complete curves (line segments). We have shown in experiment that our method achieves high computational efficiency and improved robustness to noise.

9413-25, Session 6

Adaptation of an articulated fetal skeleton model to three-dimensional fetal image data

Tobias Klinder, Philips Research (Germany); Hannes Wendland, Univ. zu Lübeck (Germany); Irina Waechter-Stehle, Philips Research (Germany); David Roundhill, Philips Healthcare (United States); Cristian Lorenz, Philips Research (Germany)

The automatic interpretation of three-dimensional fetal images poses specific challenges compared to other three-dimensional diagnostic data,

especially since the orientation of the fetus in the uterus and the position of the extremities is highly variable. In this paper, we present a comprehensive articulated model of the fetal skeleton and the adaptation of the articulation for pose estimation in three-dimensional fetal images. The model is composed out of rigid bodies where the articulations are represented as rigid body transformations. Given a set of target landmarks, the model constellation can be estimated by optimization of the pose parameters. Experiments are carried out on 3D fetal MRI data.

9413-26, Session 6

Interpretable exemplar-based shape classification using constrained sparse linear models

Gunnar A. Sigurdsson, Zhen Yang, Trac D. Tran, Jerry L. Prince, Johns Hopkins Univ. (United States)

Many types of diseases manifest themselves as observable changes in the shape of the affected organs. Using shape classification, we can look for signs of disease and discover relationships between diseases. We formulate the problem of shape classification in a holistic framework that utilizes a lossless scalar field representation and a non-parametric classification based on sparse recovery. This framework generalizes over certain classes of unseen shapes while using the full information of the shape, bypassing feature extraction. The output of the method is the class whose combination of exemplars most closely approximates the shape, and furthermore, the algorithm returns the most similar exemplars along with their similarity to the shape, which makes the result simple to interpret. Our results show that the method offers accurate classification between three cerebellar diseases and controls in a database of cerebellar ataxia patients. For reproducible comparison, promising results are presented on publicly available 2D datasets, including the ETH-80 dataset where the method achieves 88.4% classification accuracy.

9413-27, Session 6

Reference geometry-based detection of (4D-)CT motion artifacts: a feasibility study

René Werner, Tobias Gauer, Univ. Medical Ctr. Hamburg-Eppendorf (Germany)

Respiration-correlated computed tomography (4D or 3D+t CT) can be considered as standard of care in radiation therapy treatment planning for lung and/or liver lesions. The decision about an application of motion management devices and the estimation of patient-specific motion effects on the dose distribution relies on precise motion assessment in the planning 4D CT data - which is impeded in case of motion artifacts in the CT data.

The development of image-based/post-processing approaches to reduce motion artifacts would benefit from precise detection and localization of the artifacts. Simple slice-by-slice comparison of intensity values and threshold-based analysis of related metrics suffer from - depending on the threshold - high false-positive or -negative rates. In this work, we propose exploiting prior knowledge about 'ideal' (= artifact free) reference geometries to stabilize metric based artifact detection by transferring (multi-)atlas-based concepts to this specific task. Two variants are introduced and evaluated: (S1) analysis and comparison of warped atlas data obtained by repeated non-linear atlas-to-patient registration runs with different levels of regularization; (S2) direct analysis of the vector field properties (divergence, curl magnitude) of the atlas-to-patient transformation.

Feasibility of approaches (S1) and (S2) is evaluated by motion-phantom data and intra-subject experiments (4 patients) as well as - adopting a multi-atlas strategy - inter-subject investigations (12 patients). It is demonstrated that especially sorting/double structure artifacts can be precisely detected and localized by (S1). In contrast, (S2) suffers from high false positive rates.

9413-28, Session 6

Hierarchical pictorial structures for simultaneously localizing multiple organs in volumetric pre-scan CT

Qi Song, Albert Montillo, GE Global Research (United States); Bipul Das, GE India Technology Centre Pvt. Ltd. (India); Zhye Yin, GE Global Research (United States)

Parsing volumetric computed tomography (CT) into 10 or more salient organs simultaneously is a challenging task with many applications such as personalized scan planning and dose reporting. In the clinic, pre-scan data can come in the form of very low dose volumes acquired just prior to the primary scan or from an existing primary scan. To localize organs in such diverse data, we propose a new learning based framework that we call hierarchical pictorial structures (HPS) which builds multiple levels of models in a tree-like hierarchy that mirrors the natural decomposition of human anatomy from gross structures to finer structures. Each node of our hierarchical model learns (1) the local appearance and shape of structures, and (2) a generative global model that learns probabilistic, structural arrangement. Our main contribution is two fold. First we embed the pictorial structures approach in a hierarchical framework which reduces test time image interpretation and allows for the incorporation of additional geometric constraints that robustly guide model fitting in the presence of noise. Second we guide our HPS framework with the probabilistic cost maps extracted using random decision forests using volumetric 3D HOG features which makes our model fast to train and fast to apply to novel test data and posses a high degree of invariance to shape distortion and imaging artifacts. All steps require just tens of seconds to compute and all organs are located with suitably high accuracy for our clinical applications such as personalized scan planning for radiation dose reduction. We assess our method using a database of volumetric CT scans from 81 subjects with widely varying age and pathology and with simulated ultra low dose cadaver pre-scan data.

9413-29, Session 6

Skeletal shape correspondence via entropy minimization

Liyun Tu, The Univ. of North Carolina at Chapel Hill (United States) and Chongqing Univ. (China); Martin A. Styner, Jared Vicory, Beatriz Paniagua, The Univ. of North Carolina at Chapel Hill (United States); Juan Carlos Prieto, Brigham and Women's Hospital, Ctr. of Neurological Imaging (United States); Dan Yang, Chongqing Univ. (China); Stephen M. Pizer, The Univ. of North Carolina at Chapel Hill (United States)

Purpose: Improving the shape statistics of medical image objects by generating correspondence of interior skeletal points.

Data: Synthetic objects and real world lateral ventricles segmented from MR images. Method(s): Each object's interior is modeled by a skeletal representation called s-rep, which is a quadrilaterally sampled, folded 2-sided skeletal sheet with spoke vectors proceeding from the sheet to the boundary. The skeleton is divided into three parts: up-side, down-side and fold-curve. The spokes on each part are treated separately and, using spoke interpolation, are shifted along their skeletal parts in each training sample so as to tighten the probability distribution on those spokes' geometric properties while sampling the object interior regularly. As with the surface-based correspondence method of Cates et al., entropy is used to measure both the probability distribution tightness and sampling regularity. The spokes' geometric properties are skeletal position, spoke length and spoke direction. The properties used to measure the regularity are the volumetric subregions bounded by the spokes, their quadrilateral sub-area and edge lengths on the skeletal surface and on the boundary. Results: Evaluation on synthetic objects and real world lateral ventricles demonstrated improvement in the performance of statistics using the resulting probability

distributions, as compared to methods based on boundary models. The evaluation measures used were generalization, specificity, and compactness. Conclusions: S-rep models with the proposed improved correspondence provide significantly enhanced statistics as compared to standard boundary models.

9413-30, Session 7

Probabilistic atlas based labeling of the cerebral vessel tree

Martijn Van de Giessen, Leiden Univ. Medical Ctr. (Netherlands) and Technische Univ. Delft (Netherlands); Jasper P. Janssen, Patrick A. Brouwer, Johan H. C. Reiber, Leiden Univ. Medical Ctr. (Netherlands); Boudewijn P. F. Lelieveldt, Leiden Univ. Medical Ctr. (Netherlands) and Technische Univ. Delft (Netherlands); Jouke Dijkstra, Leiden Univ. Medical Ctr. (Netherlands)

Preoperative imaging the cerebral vessel tree is necessary for therapy planning for stenoses and aneurysms. Usually, a magnetic resonance angiography (MRA) or computed tomography angiography (CTA) is acquired from which the cerebral vessel tree is segmented. Accurate analysis is helped by the labeling of the cerebral vessels, but labeling is non-trivial due to anatomical topological variability and missing branches due to acquisition issues. In recent literature, labeling the cerebral vasculature around the Circle of Willis has mainly been approached as a graph-based problem. The most succesful method, however, requires the definition of all possible permutations of missing vessels, which limits application to subsets of the tree and ignores spatial information on the vessel locations.

This research aims to perform labeling using probabilistic atlases that model spatial vessel and label likelihoods. A cerebral vessel tree is aligned to a probabilistic atlas and subsequently each vessel is labeled by computing the maximum label likelihood per segment from label-specific atlases.

The proposed method was validated on 25 segmented cerebral vessel trees. Labeling accuracies were close to 100% for large vessels, but dropped to below 50% for small vessels that were only present in less than 50% of the set.

With this work we showed that using solely spatial information of the vessel labels, vessel segments from stable vessels (>50% presence) were reliably classified. This spatial information will form the basis for a future labeling strategy with a very loose topological model.

9413-31, Session 7

Simultaneous skull-stripping and lateral ventricle segmentation via fast multi-atlas likelihood-fusion

Xiaoying Tang, Kwame Kutten, Can Ceritoglu, Susumu Mori, Michael I. Miller, Johns Hopkins Univ. (United States)

In this paper, we propose a fully automated pipeline for simultaneous skull-stripping and lateral ventricle segmentation using T1-weighted images. The pipeline is built on fast multi-atlas likelihood-fusion (MALF) which utilizes multiple T1-weighted atlases that have been pre-segmented into six whole-brain labels -- the gray matter, the white matter, the cerebrospinal fluid, the lateral ventricle, the skull, and the background of the entire image. MALF was designed for estimating brain anatomical structures in the framework of diffeomorphic changes of coordinates. In the proposed pipeline, we use MALF to estimate those same six whole-brain labels in the test T1-weighted image. The three tissue labels (gray matter, white matter, and cerebrospinal fluid) and the lateral ventricle are then grouped together to form a binary mask to which we then apply morphological smoothing so as to create the final mask for brain extraction. For computational purpose, all input images to MALF are down-sampled by factor of two and small deformations are used for the changes of coordinates. This substantially reduces the

computational complexity, hence we use the term "fast MALF". The skull-stripping performance is qualitatively evaluated on a total of 475 brain scans from a preclinical Alzheimer study. Quantitative error analysis is carried out on 36 scans to evaluate the accuracy of the pipeline in segmenting the lateral ventricle.

9413-32, Session 7

A transformation similarity constraint for groupwise nonlinear registration in longitudinal neuro imaging studies

Greg M. Fleishman, Imaging Genetics Ctr., The Univ. of Southern California (United States) and Univ. of California, Los Angeles (United States); Boris Gutman, Imaging Genetics Ctr., The Univ. of Southern California (United States); P. Thomas Fletcher, Scientific Computing and Imaging Institute (United States) and The Univ. of Utah (United States); Paul M. Thompson, Imaging Genetics Ctr., The Univ. of Southern California (United States)

Patients with Alzheimer's Disease and other brain disorders often show a similar spatial distribution of volume change throughout the brain over time, but this information is not yet used in registration algorithms to refine the quantification of change. Here, we develop a mathematical basis to incorporate that information into a longitudinal structural Neuro Imaging study. We modify the canonical minimization problem for non-linear registration to include a term that couples a collection of registrations together to enforce group similarity. By doing this, we simultaneously learn a pattern of change common within the group and use that pattern to regularize the developing transformations. The Euler-Lagrange equations for the coupling term are presented and a gradient descent algorithm based on the formulation was implemented. We tested the algorithm on a toy dataset to illustrate the expected behavior of the algorithm. The algorithm was further tested on a small pilot test set of real 3D MRI scans from the Alzheimer's Disease Neuro Imaging Initiative (ADNI) to assess its performance on real data. Qualitatively, when compared to traditional registration, the groupwise similarity constrained registration (GSCR) shows an average change map (the average Jacobian determinant image over the set of transformations) that is more sharp and focused. Quantitatively, the GSCR Jacobian determinant images have a smaller voxel-wise variance. These results support the use of GSCR for more efficient computation of a change map atlas. Such an atlas could be used to understand the pathology of a subtle disease and/or constrain future registrations to maximize power in clinical trials dependent on precise localization of effect.

9413-33, Session 7

Automatic brain extraction in fetal MRI using multi-atlas-based segmentation

Sébastien Tourbier, Ctr. d'Imagerie BioMédicale (Switzerland) and Ctr. Hospitalier Univ. Vaudois (Switzerland) and Univ. de Lausanne (Switzerland); Patric Hagmann, Ctr. Hospitalier Univ. Vaudois (Switzerland) and Univ. de Lausanne (Switzerland); Maud Cagneaux, Hôpital Femme-Mère-Enfant (France); Laurent Guibaud, Hôpital Femme Mère Enfant (France); Subrahmanyam Gorthi, Ecole Polytechnique Fédérale de Lausanne (Switzerland); Marie Schaer, Univ. de Genève (Switzerland); Jean-Philippe Thiran, Ctr. Hospitalier Univ. Vaudois (Switzerland) and Univ. de Lausanne (Switzerland) and Ecole Polytechnique Fédérale de Lausanne (Switzerland); Reto Meuli, Ctr. Hospitalier Univ. Vaudois (Switzerland) and Univ. de Genève (Switzerland); Meritxell Bach Cuadra, Ctr. d'Imagerie BioMédicale (Switzerland) and Ctr. Hospitalier Univ. Vaudois (Switzerland) and Univ. de Lausanne (Switzerland)

In fetal MRI, the brain extraction task is an essential step to guarantee the quality of solutions of the high-resolution (HR) brain reconstruction problem. This task is usually done manually, which is tedious and very time consuming. In the last five years, few works have addressed this problem. They can be split in two major groups, either in template-based segmentation or through machine learning. It has been shown in our preliminary work that deformable template-based segmentation coupled with the simplest multi-atlas fusion strategy, i.e. majority voting, could be well adapted to automatically extract both normal and abnormal pathological brains in fetal MRI. Here, we propose to extend this work with three contributions. Firstly, a global weighted voting for multi-atlas fusion (MAF) strategy is now used to perform the automatic extraction task. Secondly, a comprehensive and extensive quantitative evaluation of segmentation quality is conducted on 46 stacks in total, from fetuses aged between 25 and 36 weeks GA. It supports that the proposed approach compares similarly to the most recent machine leaning approach, with a Dice value above 0.90 in final brain segmentation. It also reveals a significant mean improvement of 3.5% (with 99% confidence interval) for the Dice value with regard to single-atlas (SA) strategy. Finally, the positive impact of MAF brain segmentation in the quality of HR brain reconstruction is investigated. We show that MAF strategy provides an enhancement in terms of reconstruction quality with 7.03dB on average (with 99% confidence interval) for the PSNR compared to SA strategy.

9413-34, Session 7

Automatic parcellation of longitudinal cortical surfaces

Manal H. Alassaf, James K. Hahn, The George Washington Univ. (United States) and Institute for Biomedical Computing (United States)

We present a novel automatic method to parcellate the cortical surface of the neonatal brain at different stages of development. A labeled brain atlas of newborn at 41 weeks gestational age (GA) is used to propagate labels of 90 anatomical regions of interest to a spatio-temporal atlas, which provides a dynamic model of brain development at each week between 28-44 GA. First, labels from the cortical volume of the newborn brain are propagated to an age-matched cortical surface from the spatio-temporal atlas. Then, labels are propagated across the cortical surfaces of each week of the spatio-temporal atlas by registering successive cortical surfaces and using a new pairing approach and an energy optimization function. This procedure incorporates local and global, spatial and temporal information when assigning the labels. The optimization is followed by two-steps refinement: filling the gaps and then merging small batches near region boundaries with their neighbors. To the authors' best knowledge, this is the first parcellated atlas of neonatal developing brain that covers weeks 28-44 GA. Thus, we have used three evaluation methods. The first evaluation incorporates ground truth parcellation to assist the validity of the proposed parcellation method, during which we gained 70-90% consistency. The second approach measures the local spatial growth of individual neuroanatomical regions over time and compares them with literature findings. The third evaluation focuses on comparing temporal points probabilistic distribution among regions across weeks. The result is a complete parcellation of 17 neonatal brain surfaces, with similar points per regions distributions across weeks.

9413-35, Session 8

3D MR ventricle segmentation in pre-term Infants with post-hemorrhagic ventricle dilation

Wu Qiu, Jing Yuan, Jessica Kishimoto, Robarts Research Institute (Canada); Yimin Chen, City Univ. of Hong Kong (China); Sandrine de Ribaupierre, Robarts Research Institute (Canada); Bernard Chiu, City University of Hong Kong (China); Aaron Fenster, Robarts Research Institute (Canada)

Intraventricular hemorrhage (IVH) or bleed within the brain is a common condition among pre-term infants that occurs in very low birth weight preterm neonates. The prognosis is further worsened by the development of progressive ventricular dilatation, i.e., post-hemorrhagic ventricle dilation (PHVD), which occurs in 10-30% of IVH patients. In practice, predicting PHVD accurately and determining if that specific patient with ventricular dilatation requires treatment requires the ability to measure accurately ventricular volume. While monitoring of PHVD in infants is typically done by repeated US and not MRI, once the patient has been treated, the follow-up over the lifetime of the patient is done by MRI. While manual segmentation is still seen as a gold standard, it is extremely time consuming, and therefore not feasible in a clinical context, and it also has a large inter- and intra-observer variability.This paper proposes an segmentation algorithm to extract the cerebral ventricles from 3D T1-weighted MR images of pre-term infants with PHVD. The proposed segmentation algorithm makes use of the convex optimization technique combined with the learned priors of image intensities and label probabilistic map, which is built from a multi-atlas registration scheme. The leave-one-out cross validation using 7 PHVD patient T1 weighted MR images showed that the proposed method yielded a mean DSC of 89.7%±4.2%, a MAD of 2.6±1.1 mm, a MAXD of 17.8±6.2 mm, and a VD of 11.6% ± 5.9%, suggesting a good agreement with manual segmentations.

9413-36, Session 8

Automatic tissue segmentation of neonate brain MR Images with subject-specific atlases

Marie Cherel, Francois Budin, The Univ. of North Carolina at Chapel Hill (United States); Marcel Prastawa, GE Global Research (United States); Guido Gerig, The Univ. of Utah (United States); Kevin Lee, The Univ. of North Carolina at Chapel Hill (United States); Claudia Buss, Charité Univ. Medicine Berlin (Germany) and Univ. of California, Irvine (United States); Amanda E. Lyall, Harvard Medical School (United States); Kirsten N. Zaldarriaga Consing, Martin A. Styner, The Univ. of North Carolina at Chapel Hill (United States)

Automatic tissue segmentation of the neonate brain using Magnetic Resonance Images (MRI) is extremely important to study brain development and perform early diagnostics but is challenging due to high variability and inhomogeneity in contrast throughout the image due to incomplete myelination of the white matter tracts. For these reasons, current methods often totally fail or give unsatisfying results. Furthermore, most of the subcortical midbrain structures are misclassified due to a lack of contrast in these regions. We have developed a novel method that creates a probabilistic subject-specific atlas based on a population atlas currently containing 12 manually segmented cases. The generated atlas is sharp and adapted to the subject that is being processed. We segment the brain using the newly created atlas with a single-atlas expectation maximization based method. Our proposed method leads to a much lower failure rate in our experiments. The overall segmentation results are considerably

improved when compared to using a non-subject-specific, population average atlas. Additionally, we have incorporated diffusion information obtained from Diffusion Tensor Images (DTI) to improve the detection of white matter that is not visible at this early age in structural MRI (sMRI) due to a lack of myelination. Although this necessitates the acquisition of an additional sequence, the diffusion information improves the white matter segmentation throughout the brain, especially for the mid-brain structures such as the corpus callosum and the internal capsule.

9413-37, Session 8

Shape-based multi-region segmentation framework: application to 3D infants MRI data

Sonia Dahdouh, Institut Mines-Telecom (France) and Télécom ParisTech (France); Isabelle Bloch, Télécom ParisTech (France) and Institut Mines-Telecom (France)

This paper presents a novel shape-guided multi-region variational region growing framework for extracting simultaneously thoracic and abdominal organs on 3D infants whole body MRI.

Due to the inherent low quality of these data, classical segmentation methods tend to fail at the multi-segmentation task.

To compensate for the low resolution and the lack of contrast and to enable the simultaneous segmentation of multiple organs, we introduce a segmentation framework on a graph of supervoxels that combines supervoxels intensity distribution weighted by gradient vector flow value and a shape prior per tissue.

The intensity-based homogeneity criteria and the shape prior, encoded using Legendre moments, are added as energy terms in the functional to be optimized.

The intensity-based energy is computed using both local (voxel value) and global (neigboring regions mean values, adjacent voxels values and distance to the neighboring regions) criteria.

Inter-region conflict resolution is handled using a weighted Voronoi decomposition method, the weights being determined using tissues densities.

The energy terms of the global energy equation are weighted using an information on growth direction and on gradient vector flow value in order to either guide the segmentation toward the image natural edges if it is consistent with image and shape prior terms or enforce the shape prior term otherwise.

Results on 3D infants MRI data are presented and compared to a set of manual segmentations.

Both visual comparison and quantitative measurements show good results.

9413-38, Session 8

LOGISMOS-B for primates: primate cortical surface reconstruction and thickness measurement

Ipek Oguz, The Univ. of Iowa (United States); Martin A. Styner, The Univ. of North Carolina at Chapel Hill (United States); Mar Sanchez, Emory Univ. (United States); Yundi Shi, The Univ. of North Carolina at Chapel Hill School of Medicine (United States); Milan Sonka, The Univ. of Iowa (United States)

Cortical thickness and surface area are important morphological measures with implications for many psychiatric and neurological conditions. Automated measurement of cortical thickness from 3D MRI scans is challenging due to the variable anatomy of the cortex and its highly

complex geometry. While many methods exist for this task in the context of the human brain, these methods are typically not readily applicable to the primate brain. We propose an innovative approach based on our recently proposed human cortical reconstruction algorithm, LOGISMOS-B, and the Laplace-based thickness measurement method. Quantitative evaluation of our approach on a dataset of four 12-month-old macaques labeled by our anatomical experts shows an average signed surface distance of 0.01 ± 0.03mm and an unsigned surface distance of 0.42 ± 0.03mm over the whole brain. Excluding the rather problematic temporal pole region further improves unsigned surface distance to 0.34 ± 0.03mm. This high level of accuracy reached by our algorithm even in this challenging developmental dataset illustrates its robustness and its potential for primate brain studies.

9413-39, Session 8

Robust detection of multiple sclerosis lesion from intensity-normalized multi-channel MRI

Yogesh Karpate, Olivier Commowick, Christian Barillot, Univ. of Rennes 1 (France)

 Multiple sclerosis (MS) is a disease with heterogeneous evolution among the patients. Quantitative analysis of longitudinal Magnetic Resonance Images (MRI) provides a spatial analysis of the brain tissues which may lead to the discovery of biomarkers of disease evolution. Better understanding of the disease will lead to a better discovery of pathogenic mechanisms, allowing for patient-adapted therapeutic strategies. To characterize MS lesions, we propose a novel paradigm to detect white matter lesions based on a statistical framework. It aims at studying the benefits of using multi-channel MRI to detect statistically significant differences between each individual MS patient and a database of control subjects. This framework consists in two components. First, intensity standardization is conducted to minimize the inter-subject intensity difference arising from variability of the acquisition process and different scanners. The intensity normalization maps parameters obtained using a robust Gaussian Mixture Model (GMM) estimation not affected by the presence of MS lesions. The second part studies the comparison of multi-channel MRI of MS patients with respect to an atlas built from the control subjects, thereby allowing us to look for differences both in normal appearing white matter but also in and around the lesions of each patient. Experimental results demonstrate that our technique accurately detects significant differences in lesions consequently improving the results of MS lesion detection.

9413-40, Session 8

Evaluation of an automatic brain segmentation method developed for neonates on adult MR brain images

Pim Moeskops, Max A. Viergever, Manon J. N. L. Benders, Ivana Isgum, Univ. Medical Ctr. Utrecht (Netherlands)

Automatic brain tissue segmentation is of clinical relevance in images acquired at all ages. The literature presents a clear distinction between methods developed for MR images of infants, and methods developed for images of adults. The aim of this work is to evaluate a method developed for neonatal images in the segmentation of adult images. The evaluated method employs supervised voxel classification in subsequent stages, exploiting spatial and intensity information. Evaluation was performed using images available within the MRBrainS13 challenge. The obtained average Dice coefficients were 85.77% for grey matter, 88.66% for white matter, 81.08% for cerebrospinal fluid, 95.65% for cerebrum, and 96.92% for intracranial cavity, currently resulting in the best overall ranking. The possibility of applying the same method to neonatal as well as adult images can be of great value in cross-sectional studies including a wide age range.

9413-41, Session 9

Active contour based segmentation of resected livers in CT images

Simon Oelmann, Fraunhofer-Institut für Graphische Datenverarbeitung (Germany); Cristina Oyarzun Laura, Klaus Drechsler, Stefan Wesarg, Fraunhofer-Institut für Graphische Datenverarbeitung (Germany) and Technischen Univ. Darmstadt (Germany)

The majority of state of the art segmentation algorithms are able to give proper results in healthy organs but not in pathological ones. However, many clinical applications require an accurate segmentation of pathological organs. Examples of this are the determination of the target boundaries for radiotherapy or liver volumetry calculations. Volumetry measurements are of special interest after tumor resection for follow up of liver regrow. The segmentation of resected livers presents additional challenges that were not addressed by state of the art algorithms. This paper presents a snakes based algorithm specially developed for the segmentation of resected livers. The algorithm is enhanced with a novel dynamic smoothing technique that allows the active contour to propagate with different speeds depending on the intensities visible in its neighborhood. The algorithm is evaluated in 6 clinical CT images as well as 18 artificial datasets that generated from additional clinical CT images.

9413-42, Session 9

FIST: a fast interactive segmentation technique

Dirk R. Padfield, Rahul Bhotika, GE Global Research (United States); Alexander Natanzon, Intellifunction (United States)

Radiologists are required to read thousands of patient images every day, and any tools that can improve their workflow to help them make efficient and accurate measurements is of great value. Such an interactive tool must be intuitive to use, and we have found that users are accustomed to clicking on the contour of the object for segmentation and would like the final segmentation to pass through these points. The tool must also be fast to enable real-time interactive feedback. To meet these needs, we present a segmentation workflow that enables an intuitive method for fast interactive segmentation of 2D and 3D objects. Given simple user clicks on the contour of an object in one 2D view, the algorithm generates foreground and background seeds and computes foreground and background distributions that are used to segment the object in 2D. It then propagates the information to the two orthogonal planes in a 3D volume and segments all three 2D views. The automated segmentation is automatically updated as the user continues to add points around the contour, and the algorithm is re-run using the total set of points. Based on the segmented objects in these three views, the algorithm then computes a 3D segmentation of the object. This process requires only limited user interaction to segment complex shapes and significantly improves the workflow of the user.

9413-43, Session 9

A supervoxel-based segmentation for prostate MR images

Zhiqiang Tian, Lizhi Liu, Baowei Fei, Emory Univ. (United States)

Accurate segmentation of the prostate has many applications in prostate cancer diagnosis and therapy. In this paper, we propose a "Supervoxel" based method for prostate segmentation. The prostate segmentation is considered as the minimization of an energy function where variables are labels of the superpvoxels. The data term estimates the likelihood of

a supervoxel belongs to the prostate according to a shape feature. The geometric relationships between two neighboring supervoxels are used to construct a smoothness term. The 3D graph cut is used to minimize the energy function to segment the prostate. Then a 3D level set is used to get a smooth surface based on the output of graph cut. The performance of the proposed algorithm was evaluated with respect to the manual segmentation ground truth. The experimental results on 12 prostate volumes showed that the proposed algorithm achieved satisfactory results. The segmentation method can be used not only for the prostate but also for other organs.

9413-44, Session 9

A new 3D neurovascular bundles (NVB) segmentation method based on MR-TRUS deformable registration

Xiaofeng Yang, Peter Rossi, Tomi Ogunleye, Ashesh Jani, Walter Curran, Tian Liu, Emory Univ. (United States)

In this paper we propose a 3D NVB segmentation method for ultrasound (US) image by integrating MR and transrectal ultrasound (TRUS) images through MR-TRUS deformable registration. First, 3D neurovascular bundles (NVB) are contoured in MR images captured before radiotherapy (RT) by a physician, and then 3D MR-defined NVB are transformed into US images by the MR-TRUS registration method, which models the prostate tissue as an elastic material, and jointly estimates the boundary deformation and the volumetric deformations under elastic constraint. This technique was validated with a clinical study of 7 patients undergoing RT treatment for prostate cancer. The accuracy of our approach was assessed through the locations of landmarks, as well as previous ultrasound Doppler images of patients. MR-TRUS registration was successfully performed for all patients. The mean displacement of the landmarks between the post-registration MR and TRUS images was 1.56±0.37 mm, and the NVB volume Dice Overlap Coefficient was 92.1±3.2%. We have developed a new approach to improve 3D NVB segmentation through MR-TRUS registration for prostate RT, demonstrated its clinical feasibility, and validated its accuracy with ultrasound Doppler data. This technique could be a useful tool as we try to spare the NVB in prostate RT, monitor NBV response to RT, and potentially improve post-RT potency outcomes.

9413-45, Session 9

Pancreas segmentation from 3D abdominal CT images using patient-specific weighted-subspatial probabilistic atlases

Kenichi Karasawa, Masahiro Oda, Yuichiro Hayashi, Yukitaka Nimura, Nagoya Univ. (Japan); Takayuki Kitasaka, Aichi Institute of Technology (Japan); Kazunari Misawa, Aichi Cancer Ctr. Hospital (Japan); Michitaka Mujiwara, Graduate School of Medicine, Nagoya Univ. (Japan); Kensaku Mori, Nagoya Univ. (Japan); Daniel Rueckert, Department of Computing, Imperial College (United Kingdom)

In this paper, we propose a new pancreas segmentation method from 3D abdominal CT volumes using patient-specific weighted-subspatial probabilistic atlases.

We use a the nonrigid registration method to register these training VOIs to an input VOI.

After calculating the similarities between each training VOI and the input VOI based on the registration result,

training data having the top N similarities and the input VOI are then subspatially divided into some cubic regions.

We use a the nonrigid registration method again.

After integrating these probabilistic atlases into one, we perform a rough-to-precise segmentation of the pancreas using this atlas.

The results of the experiments showed that utilization of the training data having the top N similarities in the Step 1 led good results of the pancreas segmentation.

The Jaccard Index and the average surface distance of the result were 58.3% and 1.33mm on average, respectively.

9413-46, Session 10

Random local binary pattern based label learning for multi-atlas segmentation

Hancan Zhu, Hewei Cheng, Yong Fan, Institute of Automation (China)

Multi-atlas based segmentation methods have attracted growing attention in the field of medical image segmentation. Under the framework of multi-atlas based segmentation, atlas images are first registered to the target image space and their corresponding label images are propagated to the target space with the obtained transformation. It has been demonstrated that image intensity information itself is not discriminative enough for distinguishing different subcortical structures in brain magnetic resonance (MR) images. Recent advance in multi-atlas based segmentation has witnessed success of label fusion based on informative image features. The key component in these methods is feature extraction. Besides conventional image feature extraction methods, such as textural feature extraction, deep learning based methods have also been adopted in multi-atlas based segmentation. Different from conventional image feature extraction methods, the deep learning based methods are data-driven. However, they typically require huge training samples. In this paper, we propose a random local binary pattern (RLBP) method to generate image features. Based on RLBP features, we use a local learning strategy to fuse labels in multi-atlas based segmentation. Our method has been validated for segmenting hippocampus from MR images. The experiment results have demonstrated that our method can achieve competitive segmentation performance as the state-of-the-art methods.

9413-47, Session 10

Multi-output decision trees for lesion segmentation in multiple sclerosis

Amod Jog, Aaron Carass, Johns Hopkins Univ. (United States); Dzung L. Pham, Henry M. Jackson Foundation (United States); Jerry L. Prince, Johns Hopkins Univ. (United States)

Multiple Sclerosis~(MS) is a disease of the central nervous system in which the protective myelin sheath of the neurons is damaged. MS leads to the formation of lesions, predominantly in the white matter of the brain and the spinal cord. The number and volume of lesions visible in magnetic resonance~(MR) imaging~(MRI) are important criteria for diagnosing and tracking the progression of MS. Locating and delineating lesions manually requires tedious and expensive efforts of highly trained raters. In this paper, we propose an automated algorithm to segment lesions in MR images using multi-output decision trees. We evaluated our algorithm on the publicly available MICCAI 2008 MS Lesion Segmentation Challenge training dataset of 20 subjects, and showed improved results in comparison to state-of-the-art methods.

We also evaluated our algorithm on an in-house dataset of 49 subjects with good results.

9413-48, Session 10

Trabecular bone class mapping across resolutions: translating methods from HR-pQCT to clinical CT

Alexander Valentinitsch, Klinikum rechts der Isar, Technische Univ. München (Germany); Lukas Fischer, Janina M. Patsch, Medizinische Univ. Wien (Austria); Jan S. Bauer, Klinikum rechts der Isar, Technische Univ. München (Germany); Franz Kainberger, Georg Langs, Mattew D. DiFranco, Medizinische Univ. Wien (Austria)

Motivated by promising clinical applications of trabecular microarchitectural class (TMACs) assessment in osteoporotic women and lung transplant recipients using high-resolution peripheral quantitative computed tomography (HR-pQCT), we extend the method to multi-detector CT (MDCT) images in order to enhance the clinical relevance by validating their reproducibility at lower, anisotropic resolutions.

Twelve right forearms were obtained from human cadavers of males and females. HR-pQCT scans were performed using the standard in vivo protocol of the scanner. MDCT images were acquired using a 64-slice scanner with two optimized protocols, differing only in tube current-time product. TMACs were calculated and visualized via "bone quality maps" for each of the 12 cadaver specimens for both modalities. They represent the following main features: TMAC1 is rich in thick trabeculae with low intertrabecular spacing. TMAC2 is characterized by trabeculae of intermediate morphometric properties. TMAC3 contains thin, inhomogeneous trabeculae and demonstrates high intertrabecular spacing. To assess variability between TMACs from different modalities and protocols, cluster volume fraction (CL.V/TV) was calculated and compared using a repeated measures ANOVA with subsequent Bonferroni correction. Comparison of TMACs in the radii imaged using both HRpQCT and MDCT yields a mean Dice score of up to 0.717 ± 0.040 and visually concordant bone quality maps. Furthermore, TMAC results from two MDCT protocols with effective doses of 81.8 and 163.5 ?Sv, respectively, showed minimal differences. Further work to develop clinically viable bone quantitative imaging using HR-pQCT validation techniques could have a significant impact on overall bone health assessment.

9413-49, Session 10

Cerebral microbleed segmentation from susceptibility weighted images

Snehashis Roy, Henry M. Jackson Foundation (United States); Amod Jog, Johns Hopkins Univ. (United States); Elizabeth Magrath, Henry M. Jackson Foundation (United States); John A. Butman, National Institutes of Health (United States); Dzung L. Pham, Henry M. Jackson Foundation (United States)

Cerebral microbleeds (CMB) are a common marker of traumatic brain injury. Accurate detection and quantification of the CMBs are important for better understanding the progression and prognosis of the injury. Previous microbleed detection methods have suffered from a high rate of false positives, which is time consuming to manually correct. In this paper, we propose a fully automatic example-based method to segment CMBs from susceptibility-weighted (SWI) scans, where examples from an already segmented template SWI image are used to detect CMBs in a new image. First, multiple radial symmetry transforms (RST) are performed on the template SWI to detect small ellipsoidal structures, which serve as potential microbleed candidates. Then 3D patches from the SWI and its RSTs are combined to form a feature vector at each voxel of the image. A random forest regression is trained using the feature vectors, where the dependent variable is the binary segmentation voxel of the template. Once the regression is learnt, it is applied to a new SWI scan, whose feature vectors contain patches from SWI and its RSTs. Experiments on 26 subjects

with mild to severe brain injury show a CMB detection sensitivity of 85.7%, specificity 99.5%, and a false positive to true positive ratio of 1.73, which is better than competing methodswith a significant reduction in computation time.

9413-50, Session 10

Rotation invariant eigenvessels and auto-context for retinal vessel detection

Alessio Montuoro, Christian Simader, Georg Langs, Ursula Schmidt-Erfurth, Medizinische Univ. Wien (Austria)

Retinal vessels are one of the few anatomical landmarks that are clearly visible in various imaging modalities of the eye. As they are also relatively invariant to disease progression retinal vessel segmentation allows cross-modal and temporal registration enabling exact diagnosing for various eye diseases like diabetic retinopathy, hypertensive retinopahty or age-related macular degeneration (AMD).

Due to the clinical significance of retinal vessels many different approaches for segmentation have been published in the literature. In contrast to other segmentation approaches our method is not specifically tailored to the task of retinal vessel segmentation. Instead we utilize a more general image classification approach and show that this can achieve comparable results.

In the proposed method we utilize the concepts of eigenfaces and auto-context.

Eigenfaces have been described quite extensively in the literature and their performance is well known. They are however quite sensitive to translation and rotation. The former was addressed by computing the eigenvessels in local image windows of different scales, the latter by estimating and correcting the local rotation.

Auto-context aims to incorporate automatically generated context information into the training phase of classification approaches. It has been shown to improve the performance of spinal cord segmentation and 3D brain image segmentation.

9413-51, Session 10

Deep convolutional networks for pancreas segmentation in CT imaging

Holger R. Roth, Amal Farag, Le Lu, Evrim B. Turkbey, Ronald M. Summers, National Institutes of Health (United States)

Automatic organ segmentation is an important prerequisite for many computer-aided diagnosis systems. The high anatomical variability of organs in the abdomen, such as the pancreas, prevents previous segmentation methods from achieving high accuracies when compared to state-of-the-art segmentation of organs like the liver, heart or kidneys. Recently, the availability of large annotated training sets and the accessibility of affordable parallel computing resources via GPUs has made it feasible for "deep learning" methods such as convolutional networks (ConvNets) to succeed in image classification tasks.

We present a fully-automated bottom-up method for pancreas segmentation in computed tomography (CT) images of the abdomen. The method is based on hierarchical coarse-to-fine classification of local image regions (superpixels). Superpixels are extracted from the abdominal region using Simple Linear Iterative Clustering (SLIC). An initial probability response map is generated, using patch-level confidences and a two-level cascade of random forest classifiers, from which superpixel regions with >0.5 probabilities are retained. These retained superpixels serve as a highly sensitive initial input of the pancreas and its surroundings to a ConvNet that samples the bounding box of each superpixel at different scales (and random non-rigid deformations at training time) in order to assign a more distinct probability of each superpixel region being pancreas or not.

We evaluate our method on CT images of 80 patients. Using ConvNets we

achieve an improvement from the initial retained superpixels maximum Dice coefficients from 15% to 70% in testing. This shows promise for more accurate pancreas segmentation, using deep learning.

9413-52, Session 11

Robust bladder image registration by redefining data-term in total variational approach

Sharib Ali, Christian Daul, Ernest Galbrun, Univ. de Lorraine (France) and Ctr. de Recherche en Automatique de Nancy (France); Marine Amouroux, Université de Lorraine (France) and CRAN (France); François H. Guillemin, Univ. de Lorraine (France) and Ctr. de Recherche en Automatique de Nancy (France) and Institut de Cancérologie de Lorraine (France); Walter C. P. M. Blondel, Univ. de Lorraine (France) and Ctr. de Recherche en Automatique de Nancy (France)

Cystoscopy is the standard procedure for clinical diagnosis of bladder cancer. Bladder carcinoma in situ are often multifocal and spread over large areas. In vivo, localization and follow-up of these tumors and their nearby sites is necessary. But, due to the small field of view (FOV) of the cystoscopic video images, urologists cannot easily interpret the scene. Bladder mosaicing using image registration facilitates this interpretation through the visualization of entire lesions with respect to anatomical landmarks. The reference white light (WL) modality is affected by a strong variability in terms of texture, illumination conditions and motion blur. Moreover, in the complementary fluorescence light (FL) modality, the texture is visually different from that of the WL. Existing algorithms were developed for a particular modality and scene conditions. This paper proposes a more general on fly image registration approach for dealing with these variabilities in cystoscopy. To do so, we present a novel, robust and accurate image registration scheme by redefining the data-term of the classical total variational (TV) approach. Quantitative results on realistic bladder phantom images are used for verifying accuracy and robustness of the proposed model. This method is also tested in the frame of patient data mosaicing.

9413-53, Session 11

Joint registration of location and orientation of intravascular ultrasound pullbacks using a 3D graph based method

Ling Zhang, Andreas Wahle, Zhi Chen, Li Zhang, Richard Downe, The Univ. of Iowa (United States); Tomas Kovarnik M.D., 2nd Department of Internal Medicine of General University Hospital in Prague and Charles University (Czech Republic); Milan Sonka, The Univ. of Iowa (United States)

A novel method for simultaneous alignment and co-registration of baseline and follow-up intravascular ultrasound (IVUS) pullbacks is reported. The main idea is to represent the alignment and co-registration problem as a 3D graph optimization problem (finding a minimum-cost path) solvable by dynamic programming. Thus, global optimality of the resulting alignment and co-registration is guaranteed according to the employed cost function and node connections. The cost function integrates information related to vessel/plaque morphology, plaque components and perivascular image data. The node connections incorporate the prior information about angular twisting between consecutively co-registered IVUS image pairs. Pilot validation of our method is currently available for four pairs of IVUS pullback sequences consisting of 323 IVUS image frames from four patients. Results showed the average alignment and co-registration errors were 0.26 mm

and 5.2°, respectively. Compared with our previous results, the new method offers significant alignment improvement ($p < 0.001$). The final version of this work will present results from co-registering 51 IVUS pullback pairs containing 15,209 IVUS image frames.

9413-54, Session 11

Optimal-mass-transfer-based estimation of glymphatic transport in living brain

Vadim Ratner, Liangjia Zhu, Ivan Kolesov, Stony Brook Univ. (United States); Maiken Nedergaard, Rochester Univ. (United States); Helene Benveniste, Allen R. Tannenbaum, Stony Brook Univ. (United States)

It was recently shown that the brain-wide cerebrospinal fluid (CSF) and interstitial fluid exchange system designated the 'glymphatic pathway' plays a key role in removing waste products from the brain, similarly to the lymphatic system in other body organs. It is therefore important to study the flow patterns of glymphatic transport through the live brain in order to better understand its functionality in normal and pathological states. Unlike blood, the CSF does not flow rapidly through a network of dedicated vessels, but rather through para-vascular channels and brain parenchyma in a slower time-domain, and thus conventional fMRI or other blood-flow sensitive MRI sequences do not provide much useful information about the desired flow patterns. We have accordingly analyzed a series of MRI images, taken at different times, of the brain of a live rat, which was injected with a paramagnetic tracer into the CSF via the lumbar intrathecal space of the spine. Our goal is twofold: (a) find glymphatic (tracer) flow directions in the live rodent brain; and (b) provide a model of a (healthy) brain that will allow the prediction of tracer concentrations given initial conditions. We model the liquid flow through the brain by the diffusion equation. We then use the Optimal Mass Transfer (OMT) approach to derive the glymphatic flow vector field, and estimate the diffusion tensors by analyzing the (changes in the) flow. Simulations show that the resulting model successfully reproduces the dominant features of the experimental data.

9413-55, Session 11

Robust temporal alignment of multimodal cardiac sequences

Andrea Perissinotto, Life and Health Sciences Research Institute (Portugal); Sandro Queirós, Life and Health Sciences Research Institute (Portugal) and Katholieke Univ. Leuven (Belgium) and Univ. do Minho (Portugal); Pedro Morais, Life and Health Sciences Research Institute (Portugal); Maria J. Baptista, Life and Health Sciences Research Institute (Portugal); Mark Monaghan, King's College Hospital (United Kingdom); Nuno F. Rodrigues, Life and Health Sciences Research Institute (Portugal) and Univ. do Minho (Portugal) and DIGARC, Instituto Politécnico do Cávado e do Ave (Portugal); Jan D'hooge, KU Leuven (Belgium); João L. Vilaça, Daniel Barbosa, Life and Health Sciences Research Institute (Portugal) and DIGARC, Instituto Politécnico do Cávado e do Ave (Portugal)

Background: Given the dynamic nature of cardiac function, correct temporal alignment of pre-operative models and intra-operative images is crucial for augmented reality in cardiac image-guided interventions. As such, the current study focus on the development of an image-based strategy for temporal alignment of multimodal cardiac imaging sequences, such as cine Magnetic Resonance Imaging (MRI) or 3D Ultrasound (US).

Materials and Method: First, we derive a robust, modality independent

signal from the image sequences, estimated by computing the normalized cross-correlation between each frame in the temporal sequence and the end-diastolic frame. This signal is a surrogate for the LV volume curve over time, whose variation indicates different temporal landmarks of the cardiac cycle. We then perform the temporal alignment of these surrogate signals derived from MRI and US sequences of the same patient through Dynamic Time Warping (DTW) algorithm.

Results: The proposed framework was evaluated in 98 volunteers, which have undergone both 3D+t MRI and US scans. The end-systolic frame could be accurately estimated as the minimum of the image-derived surrogate signal, presenting a relative error of 1.6±1.9% and 4.0±4.2% for the MRI and US sequences, respectively. The use of DTW reduces the desynchronization of the cardiac events in MRI and US sequences, allowing to temporally align multimodal cardiac imaging sequences.

Conclusion: A generic, fast and accurate method for temporal synchronization of MRI and US sequences of the same patient was introduced. This approach could be straightforwardly used for the correct temporal alignment of pre-operative MRI information and intra-operative US images.

9413-56, Session 11

Relating speech production to tongue muscle compressions using tagged and high-resolution magnetic resonance imaging

Fangxu Xing, Chuyang Ye, Johns Hopkins Univ. (United States); Jonghye Woo, Univ. of Maryland, Baltimore (United States) and Johns Hopkins Univ. (United States); Maureen L. Stone, Univ. of Maryland, Baltimore (United States); Jerry L. Prince, Johns Hopkins Univ. (United States)

The human tongue is composed of multiple internal muscles that work collaboratively during the production of speech. Assessment of muscle mechanics can help understand the creation of tongue motion, interpret clinical observations, and predict surgical outcomes. Although various methods have been proposed for computing the tongue's motion, associating motion with muscle activity in an interdigitated fiber framework has not been studied. In this work, we aim to develop a method that reveals different tongue muscles' activities in different time phases during speech. We use four-dimensional tagged magnetic resonance (MR) images and static high-resolution MR images to obtain tongue motion and muscle anatomy, respectively. Then we compute strain tensors and local tissue compression along the muscle fiber directions in order to reveal their activation. This process relies on the support from multiple image analysis methods, including super-resolution volume reconstruction from MR image slices, segmentation of internal muscles, tracking the incompressible motion of tissue points using tagged images, propagation of muscle fiber directions over time, and calculation of strain in the line of action, etc. We evaluated the method on a control subject and two post-glossectomy patients in a controlled speech task. The normal subject's tongue muscle activity shows high correspondence with the production of speech in different time instants, while both patients' muscle activities show different patterns from the control due to their resected tongues. This method shows potential for relating overall tongue motion to particular muscle activity, which may provide novel information for future clinical and scientific studies.

9413-57, Session 12

Automatic assessment of volume asymmetries applied to hip abductor muscles in patients with hip arthroplasty

Christian Klemt, Marc Modat, Jonas Pichat, Manuel

J. Cardoso, Univ. College London (United Kingdom); Joahnn Henckel, Alister Hart, Institute of Orthopaedics & Musculoskeletal Science (United Kingdom); Sébastien Ourselin, Univ. College London (United Kingdom)

Metal-on-metal (MoM) hip arthroplasties have been utilised over the last decade to restore hip function for 1.5million patients worldwide. Although widely used, this hip arthroplasty releases metal wear debris which lead to muscle atrophy. The degree of muscle wastage differs across patients ranging from mild to severe. The longterm outcomes for patients with MoM hip arthroplasty are reduced for increasing degrees of muscle atrophy, highlighting the need to automatically segment pathological muscles. The automated segmentation of pathological soft tissues is challenging as these lack distinct boundaries and morphologically differ across patients. As a result, there is no method reported in the literature which has been successfully applied to automatically segment pathological muscles. We propose the first automated framework to delineate severely atrophied muscles by applying a novel automated segmentation propagation framework to patients with MoM hip arthroplasty. The proposed framework was used to automatically quantify muscle wastage in these patients.

9413-58, Session 12

Evaluation of five image registration tools for abdominal CT

Christopher P. Lee, Zhoubing Xu, Ryan P. Burke, Rebeccah B. Baucom, Benjamin K. Poulose, Richard G. Abramson, Bennett A. Landman, Vanderbilt Univ. (United States)

Image registration has become an essential image processing technique to compare data across time and individuals. With the successes in volumetric brain registration, general-purpose software tools are beginning to be applied to abdominal computed tomography (CT) scans. Herein, we evaluate five current tools for registering clinically acquired abdominal CT scans. Twelve abdominal organs were labeled on a set of 20 atlases to enable assessment of correspondence. The 20 atlases were pairwise registered based on only intensity information with five registration tools (affine IRTK, FNIRT, Non-Rigid IRTK, NiftyReg, and ANTs). Following the brain literature, the Dice similarity coefficient (DSC), mean surface distance, and Hausdorff distance were calculated on the registered organs individually. However, interpretation was confounded due to a significant proportion of outliers. Examining the retrospectively selected top 1 and 5 atlases for each target revealed that there was a substantive performance difference between methods. To further our understanding, we constructed majority vote segmentation with the top 5 DSC values for each organ and atlas. The results illustrated a median improvement of 85% in DSC between the raw results and majority vote. These experiments show that some images may be well registered to some targets using the available software, but there is significant room for improvement and reveals the need for innovation and research in the field of image registration in abdominal CTs. If image registration is to be used for local interpretation of abdominal CT, great care must be taken to account for outliers (e.g., atlas selection in statistical fusion).

9413-59, Session 12

Remapping of digital subtraction angiography on a standard fluoroscopy system using 2D-3D registration

Mazen G. Alhrishy, Alexis Guyot, Andreas Varnavas, King's College London (United Kingdom); Tom Carrell, Guy's and St Thomas' NHS Foundation Trust (United Kingdom); Andrew P. King, Graeme P. Penney, King's College London (United Kingdom)

Fluoroscopy-guided endovascular interventions are being performing for more and more complex cases with longer screening times. However, X-ray is much better at visualizing interventional devices and dense structures compared to vasculature.To visualise vasculature, angiography screening is essential but requires the use of iodinated contrast medium (ICM) which is nephrotoxic. Acute kidney injury is the main life-threatening complication of ICM. Digital subtraction angiography (DSA) is also often a major contributor to overall patient radiation dose (81% reported). Furthermore, a DSA image is only valid for the current interventional view and not the new view once the C-arm is moved. In this paper, we propose the use of 2D-3D image registration between intraoperative images and the preoperative CT volume to facilitate DSA remapping using a standard fluoroscopy system. This allows repeated ICM-free DSA and has the potential to enable a reduction in ICM usage and radiation dose. Experiments were carried out using 9 clinical datasets. In total, 41 DSA images were remapped. For each dataset, the maximum and averaged remapping accuracy error were calculated and presented. Numerical results showed an overall averaged error of 2.50 mm, with 7 patients scoring averaged errors < 3 mm and 2 patients < 6 mm.

9413-60, Session 12

Discontinuous non-rigid registration using extended free-form deformations

Rui Hua, José M. Pozo, Zeike A. Taylor, Alejandro F. Frangi, The Univ. of Sheffield (United Kingdom)

This paper presents a novel method to treat discontinuities in a 3D piece-wise non-rigid registration framework, coined as EXtended Free-Form Deformation (XFFD). Existing discontinuities in the image, such as sliding motion of the lungs, should be handled to obtain physically plausible deformation fields for motion analysis. However, conventional Free-Form Deformations (FFDs) impose continuity over the whole image, introducing inaccuracy near discontinuity boundaries.

The proposed method incorporates enrichment functions into the FFD formalism, inspired by the interpolation method in the EXtended Finite Element Method (XFEM) [1]. Enrichment functions enable B-splines to handle discontinuities with minimal increase of computational complexity, while avoiding boundary-matching problem. It retains all desirable properties of the framework of FFDs yet seamlessly handles general discontinuities and can also coexist with other proposed improvements of the FFD formalism.

The XFFD showed high performance on synthetic images and 3D lung CT images. The target registration error for the CT images is 2.07±1.44 mm (less than a voxel size), compared to that of previous methods in the range from 1.36±0.99 mm to 2.14±1.82 mm. The results of XFFD are comparable to the previous methods, while having slightly higher error than the best ones, since it is designed to be a generic method, which does not assume any type of motion constraint. Therefore, it does not include any penalty term or extra parameters. However, any of these terms could be included to achieve higher accuracy for specific applications.

9413-61, Session 12

Using image synthesis for multi-channel registration of different image modalities

Min Chen, Amod Jog, Aaron Carass, Jerry L. Prince, Johns Hopkins Univ. (United States)

This paper presents a multi-channel approach for performing registration between magnetic resonance (MR) images with different modalities. In general, a multi-channel registration cannot be used when the moving and target images do not have analogous modalities. In this work, we address this limitation by using a random forest regression technique to synthesize the missing modalities from the available ones. This allows a single channel registration between two different modalities to be converted into a multi-channel registration with two mono-modal channels. To validate our approach, two openly available registration algorithms and five cost functions were used to compare the label transfer accuracy of the registration with (and without) our multi-channel synthesis approach. Our results show that the proposed method produced statistically significant improvements in registration accuracy (at an alpha level of 0.001) for both algorithms and all cost functions when compared to a standard multi-modal registration using the same algorithms with mutual information.

9413-62, Session 12

Getting the most out of additional guidance information in deformable image registration by leveraging multi-objective optimization

Tanja Alderliesten, Academisch Medisch Centrum (Netherlands); Peter A. N. Bosman, Ctr. voor Wiskunde en Informatica (Netherlands); Arjan Bel, Academisch Medisch Centrum (Netherlands)

Incorporating additional guidance information (GI), e.g., landmark/contour correspondence, in deformable image registration is often desirable and is typically done by adding constraints or cost terms to the optimization function. Commonly, deciding between a "hard" constraint and a "soft" additional cost term as well as the weighting of cost terms in the optimization function is done on a trial-and-error basis. The aim of this study is to investigate the advantages of exploiting GI from a multi-objective optimization perspective. Hereto, next to objectives related to match quality and amount of deformation, we define a third objective related to GI. Multi-objective optimization eliminates the need to a-priori tune a weighting of objectives in a single optimization function or the strict requirement of fulfilling hard guidance constraints. Instead, Pareto-efficient trade-offs between all objectives are found, effectively making the introduction of GI straightforward, independent of its type or scale. Further, since complete Pareto fronts also contain less interesting parts (i.e., solutions with near-zero deformation effort), we study how adaptive steering mechanisms can be incorporated to automatically focus more on solutions of interest. We performed experiments on artificial and real clinical data with large differences, including disappearing structures. Results show the substantial benefit of using additional GI. Moreover, compared to the 2-objective case, additional computational cost is negligible. Finally, with the same computational budget, use of the adaptive steering mechanism provides superior solutions in the area of interest.

9413-63, Session PSWed

Liver segmentation by using iterative and hybrid strategy for CT images

Dengwang Li, Shandong Normal Univ. (China); Jie Wang, Univ. of Jinan (China); Jinhu Chen, Yong Yin, Shandong Cancer Hospital and Institute (China)

Purpose: In order to improve the liver segmentation accuracy, a novel liver segmentation method is proposed by combining MRF (Markov Random Field) with SSC (Sparse Shape Composition) model for CT images.

Methods: Firstly, parameters for MRF are estimated, and then the liver shape dictionary is established based on panel data. Secondly, the liver region of an input CT image is initialized based on atlas construction. Thirdly, the liver is segmented accurately by performing the iteration step. The key component of the iteration step includes two parts: MRF-based segmentation step and SSC-based shape revisal step. The liver is segmented using MRF according the region of the initialization or revised by SSC for eliminating the errors in local area, and the shape of the MRF-based segmentation result is revised using SSC for correcting the errors caused by fuzzy edge, cross interference area, et al. Finally, the aiming region is gained gradually by the iteration of the third step. The liver panel data is collected

from a large number of clinical CT images, which includes different types of liver. And the livers are drawn by physical therapist in panel data. The test samples is collected from CT images of 50 patients.

Results: The segmentation result is gaining on the ground truth gradually under the action of constant iterative step. The segmentation accuracy is measured by ROP(region overlap percentage) and RRE (Relative Region Error) in 2D CT images. Comparing with the ground truth, the average ROP is up to 96%, and the REE value can be reduced very low.

Conclusions: The proposed method can improve the segmentation accuracy effectively. In particular, the proposed method shows good performance both with accuracy and robustness for clinical CT images with the characteristics of low-contrast, edge fuzzy, and cross interference area.

9413-64, Session PSWed

Evaluating intensity normalization for multispectral classification of carotid atherosclerotic plaque

Shan Gao, Ronald van't Klooster, Leiden Univ. Medical Ctr. (Netherlands); Diederik F. van Wijk, Aart J. Nederveen, Academisch Medisch Centrum (Netherlands); Boudewijn P. F. Lelieveldt, Rob J. van der Geest, Leiden Univ. Medical Ctr. (Netherlands)

Intensity normalization is an important preprocessing step for automatic plaque analysis in MR images as most segmentation algorithms require the images to have a standardized intensity range. In this study, we derived several intensity normalization approaches with inspiration from expert manual analysis protocols, for classification of plaque from in vivo multispectral MRI. We investigated intensity normalization based on a circular region centered at lumen (nCircle); based on sternocleidomastoid muscle (nSCM); based on intensity scaling (nScaling); based on manually classified fibrous tissue (nManuFibrous) and based on automatic classified fibrous tissue (nAutoFibrous). The proposed normalizations were evaluated using three metrics: (1) Dice similarity coefficient (DSC) between manual and automatic segmentation obtained by classifiers using different normalizations; (2) correlation between proposed normalizations and normalization used by expert; (3) Mahalanobis Distance between pairs of components. In the performed classification experiments, features of normalized image, smoothed, gradient magnitude and Laplacian images at multi-scales, distance to lumen, distance to outer wall, wall thickness were calculated for each vessel wall (VW) pixel. A supervised pattern recognition system, based on a linear discriminate classifier, was trained using the manual segmentation result to classify each VW pixel to be one of the four classes: fibrous tissue, lipid, calcification, and loose matrix according to the highest posterior probability. We evaluated our method on 23 patients. Compared to the result of conventional squared region based normalization, nScaling resulted in significant increase in DSC for lipid (p = 0.006), nAutoFibrous resulted in significant increase in DSC for calcification (p = 0.004). In conclusions, it was demonstrated that the conventional region based normalization approach is not optimal and nAutoFibrous and nScaling are promising approaches deserving further studies.

9413-65, Session PSWed

Segmentation of skin strata in reflectance confocal microscopy depth stacks

Samuel C. Hames, Dermatology Research Ctr., The Univ. of Queensland School of Medicine (Australia); Marco Ardigò, San Gallicano Dermatological Institute – IRCCS (Italy); H. Peter Soyer, Dermatology Research Ctr., The Univ. of Queensland School of Medicine (Australia); Andrew P Bradley, Univ. of Queensland (Australia); Tarl W. Prow, Dermatology Research Ctr., The Univ. of Queensland School of Medicine (Australia)

Reflectance confocal microscopy is an emerging tool for imaging human skin, but currently requires expert human assessment. To overcome the need for human experts it is necessary to develop automated tools for automatically assessing reflectance confocal microscopy imagery.

This work presents a novel approach to this task, using a bag of visual words approach to represent and classify en-face optical sections from four distinct strata of the skin. A dictionary of representative features is learned from whitened and normalised patches using spherical k-means. Each image is then represented by extracting a dense array of patches and encoding each with the most similar element in the dictionary.

The proposed framework was tested on 311 depth stacks from 54 volunteers with varying degrees of photo-ageing. Parameters are tuned using leave one patient out cross validation on a training sub-set of the data, and final evaluation was performed on a held out test set.

The proposed method generates physically plausible profiles of the distinct strata of human skin and the accuracy of classification compares favourably to the inter- and intra- observer variability between both novices and experts.

9413-66, Session PSWed

Towards high-throughput mouse embryonic phenotyping: a novel approach to classifying ventricular septal defects

Xi Liang, The Univ. of Melbourne (Australia) and National Institute of Informatics (Japan); Zhongliu Xie, Imperial College London (United Kingdom) and National Institute of Informatics (Japan); Masaru Tamura, RIKEN BioResource Ctr. (Japan) and National Institute of Genetics (Japan); Toshihiko Shiroishi, National Institute of Genetics (Japan); Asanobu Kitamoto, National Institute of Informatics (Japan) and The Graduate Univ. for Advanced Studies (SOKENDAI) (Japan)

The goal of the International Mouse Phenotyping Consortium, (IMPC, www.mousephenotype.org) is to study all the over 23,000 genes in the mouse by knocking them out one-by-one for comparative analysis. Large amounts of knock-out mice have been raised, leading to a strong demand for high-throughput phenotyping technologies. The traditional means of investigation via time-consuming histological analysis is clearly unsuitable in this scenario. Medical imaging technologies such as CT and MRI therefore have been used to develop more efficient phenotyping approaches. Existing work however primarily rests on analyzing volumetric differences of anatomical structures to identify phenotypes, yet this type of methods generally fails when features are subtle, such as the presence of ventricular septal defects (VSD) in the heart, in which case assessment normally requires an expert. This study proposes, to the best of our knowledge, the first automated VSD detection system for mouse embryos. The algorithm starts with the creation of an atlas using wild-type mouse images, followed by registration of mutant images to the atlas whereby labels are back propagated to perform heart segmentation. Then the left and right ventricles are further segmented using a region growing technique, and VSD detection is completed by checking the existence of an overlap between the two ventricle segmentations. Our approach was validated on a database of 15 mouse embryo images, where the system showed an overall accuracy of 91.7%, with a sensitivity of 66.7% and specificity of 100%.

9413-67, Session PSWed

A primal dual fixed point algorithm for constrained optimization problems with applications to image reconstruction

Yuchao Tang, Nanchang Univ. (China)

Computed tomography (CT) image reconstruction problems can be solved by finding the minimization of a suitable objective function. The first-order methods for image reconstruction in CT have been popularized in recent years. These methods are interesting because they need only the first derivative information of the objective function and can solve non-smooth regularization functions. In this paper, we consider a constrained optimization problem which often appeared in the CT image reconstruction problems. For the unconstrained case, it has been studied recently. We dedicate to propose an efficient algorithm to solve the constrained optimization problem. Numerical experiments to image reconstruction benchmark problem show that the proposed algorithms can produce a better reconstructed images in signal-to-noise than the original algorithm and other state-of-the-art methods.

9413-68, Session PSWed

Cerenkov luminescence tomography based on preconditioning orthogonal matching pursuit

Haixiao Liu, Zhenhua Hu, Kun Wang, Jie Tian, Xin Yang, Institute of Automation (China)

Background:

Cerenkov luminescence imaging (CLI) is a novel optical imaging method and has been proved to be a potential substitute of the traditional radionuclide imaging such as positron emission tomography (PET) and single-photon emission computed tomography (SPECT). This imaging method inherits the high sensitivity of nuclear medicine and low cost of optical molecular imaging. To obtain the depth information of the radioactive isotope, Cerenkov luminescence tomography (CLT) is established and the 3D distribution of the isotope is reconstructed. However, because of the strong absorption and scatter, the reconstruction of the CLT sources is always converted to an ill-posed linear system which is hard to be solved.

Methods:

In this work, the sparse nature of the light source was taken into account and the preconditioning orthogonal matching pursuit (POMP) method was established to effectively reduce the ill-posedness and obtain better reconstruction accuracy. To prove the accuracy and speed of this algorithm, a heterogeneous numerical phantom experiment and an in vivo experiment were conducted. Both the traditional Tikhonov regularization method and the ordinary orthogonal matching pursuit (OMP) method were set as comparison methods. All those three reconstruction methods were conducted on the same data to calculate the distribution of Cerenkov light source from the surface photon density.

Result:

Both the simulation result and the mouse experiment showed that our reconstruction method can provide more accurate reconstruction result compared with the traditional Tikhonov regularization method and the ordinary orthogonal matching pursuit method. In the in vivo experiment, the position error of the Tikhonov regularization method, OMP method and POMP method were 2.40mm, 1.67mm, 0.97mm, respectively. The execution time of the Tikhonov regularization method, OMP method and POMP method were 2.83 s, 0.41 s, 0.37 s, respectively.

Conclusion:

The POMP reconstruction method presented by this work can obtain a relatively better reconstruction result and provide technical support for the biological application for Cerenkov luminescence.

9413-69, Session PSWed

Beam hardening correction for sparse-view CT reconstruction

Wen Lei Liu, Hongbing Lu, Junyan Rong, Qimei Liao, Peng Gao, Fourth Military Medical Univ. (China)

Beam hardening, which is caused by spectrum polychromatism of the X-ray beam, may result in various artifacts in the reconstructed image and degrade image quality. The artifacts would be further aggravated for the sparse-view reconstruction due to insufficient sampling data. Considering the advantages of the total-variation (TV) minimization in CT reconstruction with sparse-view data, in this paper, we propose a beam hardening correction method for sparse-view CT reconstruction based on Brabant's modeling. In the correction model for beam hardening, the attenuation coefficient of each voxel at the effective energy is modeled and estimated linearly, and can be applied in an iterative way. With the integration of the correction model into the forward projector of the algebraic reconstruction technique (ART), the TV minimization can recover images when only a limited number of projections are available. The proposed method does not need prior information about the beam spectrum. Preliminary validation using Monte Carlo simulations indicates that the proposed method can provide relatively good reconstructed images from sparse-view projection data, with effective suppression of artifacts caused by beam hardening. With the proposed framework and appropriate modeling of other degrading effects such as photon scattering, it may provide a new way for low-dose CT imaging.

9413-70, Session PSWed

Heritability analysis of surface-based cortical thickness estimation on a large twin cohort

Kaikai Shen, Vincent Doré, Stephen E. Rose, Jurgen Fripp, Australian e-Health Research Ctr. (Australia); Katie L. McMahon, Ctr. for Advanced Imaging, The Univ. of Queensland (Australia); Greig I. de Zubicaray, The Univ. of Queensland (Australia); Nicholas G. Martin, Queensland Institute of Medical Research (Australia); Paul M. Thompson, Institute for Neuroimaging and Informatics, The Univ. of Southern California (United States); Margaret J. Wright, Queensland Institute of Medical Research (Australia); Olivier Salvado, Australian e-Health Research Ctr. (Australia)

The aim of this abstract is to assess the heritability of cerebral cortex, based on measurements of grey matter (GM) thickness derived from structural MR images (sMRI). With data acquired from a large twin cohort (328 subjects), an automated method was used to estimate the cortical thickness, and EM-ICP surface registration algorithm was used to establish the correspondence of cortex across the population. An ACE model was then employed to compute the heritability of cortical thickness. Heritable cortical thickness measures various cortical regions, especially in frontal and parietal lobes, such as bilateral postcentral gyri, superior occipital gyri, superior parietal gyri, precuneus, the orbital part of the right frontal gyrus, right medial superior frontal gyrus, right middle occipital gyrus, right paracentral lobule, left precentral gyrus, and left dorsolateral superior frontal gyrus.

9413-71, Session PSWed

Estimating diffusion properties in complex fiber configurations based on structure-adaptive multi-valued tensor-field filtering

Jianfei Yang, Technische Univ. Delft (Netherlands) and Academisch Medisch Centrum (Netherlands); Dirk H. J. Poot, Georgius A. M. Arkesteijn, Technische Univ. Delft (Netherlands) and Erasmus MC (Netherlands); Matthan W. A. Caan, Academisch Medisch Centrum (Netherlands); Lucas J. van Vliet, Technische Univ. Delft (Netherlands); Frans M. Vos, Technische Univ. Delft (Netherlands) and Academisch Medisch Centrum (Netherlands)

Conventionally, a single rank-2 tensor is used to assess white matter integrity in diffusion tensor imaging (DTI) of the human brain. However, a single tensor fails to describe the diffusion in fiber crossings. Although a dual tensor model is able to do so, the number of parameters is doubled, which hampers a reliably dual tensor estimate in neuroimaging practice due to the low signal-to-noise ratio. How to reliably employ the dual tensor model in the estimation of diffusion properties is an ongoing challenge.

We present a framework for structure-adaptive estimation of fiber-specific diffusivity features for statistical analyses in complex fiber structures. In our framework, a tensor model will be fitted to voxels based on ARD of the local fiber structure: the single-tensor model to voxels with single fiber and the dual-tensor model to voxels with crossing fibers. A new structure-adaptive tensor-field filter is presented to improve the continuity and regularity of the estimated multi-valued tensor fields. This filter enhances the applicability of the dual-tensor model in DTI research. With structure-adaptive and reliable estimation of diffusion properties, fiber-specific diffusion features can be extracted.

The proposed method can simultaneously preserve the underlying fiber structure and enhance the continuity of DTI in complex fiber regions. It outperforms an existing denoising approach called LMMSE which is applied to the diffusion-weighted images. Track-based spatial statistics analysis of fiber-specific FA maps can detect more subtle changes of white matter tracts than the classical single-tensor-based analysis [will be added to the full paper].

9413-72, Session PSWed

Joint brain connectivity estimation from diffusion and functional MRI data

Shu-Hsien Chu, Christophe Lenglet, Keshab K. Parhi, The Univ. of Minnesota, Twin Cities (United States)

This paper presents a novel brain network model for discovering connectivity from the joint modeling of diffusion and functional magnetic resonance imaging (MRI). Our goal is to improve the estimation of structural connectivity patterns through constraints derived from functional information. In the proposed network, the nodes represent the regions providing major functionalities, and the links represent the white matter fiber bundles connecting these regions. The concept of {em information flow} is introduced and used to model the propagation of information between functional areas and through structural pathways. The {em link capacity}, i.e. ability to transfer signal, is characterized by the strength of fiber bundles approximated from the diffusion MRI (dMRI) data and tractography techniques. The {em node demand}, i.e. neural activity, is characterized by functional networks estimated from resting-state fMRI (rfMRI). These two properties form the {em link capacity} and node demand constraints, which are exploited in the proposed model. Moreover, the information flow of a link cannot exceed the demand from either end node. It is modeled as the feasibility constraint. With this set of constraints, and the proposed cost functions, solving the network optimization problem provides the structural connectivity patterns which are supported by the functional network. Feasibility is demonstrated using realistic diffusion and

functional MRI phantom data. It is shown that the proposed model recovers the maximum number of true connections, with fewest number of false connections when compared with the connectivity derived from a joint model using the expectation-maximization (EM) algorithm presented in a prior work.

9413-73, Session PSWed

Communication of brain network core connections altered in behavioral variant frontotemporal dementia but possibly preserved in early-onset Alzheimer's disease

Madelaine Daianu, Institute for Neuroimaging and Informatics, The Univ. of Southern California (United States); Neda Jahanshad, The Univ. of Southern California (United States); Mario F. Mendez, Alzheimer's Disease Research Ctr., Univ. of California Los Angeles (United States); George Bartzokis, Semel Institute (United States); Elvira E. Jimenez, Alzheimer's Disease Research Ctr., Univ. of California Los Angeles (United States); Paul M Thompson, Univ. of Southern California (United States)

Diffusion imaging and brain connectivity analyses can assess white matter deterioration in the brain, revealing underlying patterns in how brain structure declines. Fiber tractography methods can infer neural pathways and connectivity patterns, yielding sensitive mathematical metrics of network integrity. Here, we analyzed 1.5-Tesla whole-brain diffusion-weighted images from 64 participants - 15 patients with behavioral variant frontotemporal dementia (bvFTD), 19 with early-onset Alzheimer's disease (EOAD), and 30 healthy elderly controls. Using whole-brain tractography, we reconstructed structural brain connectivity networks to map connections between cortical regions. We evaluated the brain's networks focusing on the most highly central and connected regions, also known as hubs, in each diagnostic group - specifically the "high-cost" structural backbone used in global and regional communication. The high-cost backbone of the brain, predicted by fiber density and minimally short pathways between brain regions, accounted for 81-92% of the overall brain communication metric in all diagnostic groups. Furthermore, we found that the set of pathways interconnecting high-cost and high-capacity regions of the brain's communication network are globally and regionally altered in bvFTD, compared to healthy participants; however, the overall organization of the high-cost and high-capacity networks were relatively preserved in EOAD participants, relative to controls. Disruption of the major central hubs that transfer information between brain regions may impair neural communication and functional integrity in characteristic ways typical of each subtype of dementia.

9413-74, Session PSWed

Comparisons of topological properties in autism for the brain network construction methods

Min-Hee Lee, Dong Youn Kim, Sang Hyeon Lee, Jin Uk Kim, Yonsei Univ. (Korea, Republic of); Moo K. Chung, Univ. of Wisconsin-Madison (United States)

Structural brain networks can be constructed from the white matter fiber tractography of diffusion tensor imaging (DTI), and the structural characteristics of the brain can be analyzed from its networks. When brain networks are constructed by the parcellation method, their network structures change according to the parcellation scale selection and arbitrary thresholding. To overcome these issues, we modified the ?-neighbor construction method proposed by Chung et al. (2011). The purpose of

this study was to construct brain networks for 14 control subjects and 16 subjects with autism using both the parcellation and the ?-neighbor construction method and to compare their topological properties between two methods. As the number of nodes increased, connectedness decreased in the parcellation method. However in the ε-neighbor construction method, connectedness remained at a high level even with the rising number of nodes. In addition, statistical analysis for the parcellation method showed significant difference only in the path length. However, statistical analysis for the ?-neighbor construction method showed significant difference with the path length, the degree and the density.

9413-76, Session PSWed

A novel method for 4D cone-beam computer-tomography reconstruction

Hao Zhang, Univ. of Florida (United States); Justin C. Park, Univ. of Florida College of Medicine (United States); Yunmei Chen, Univ. of Florida (United States); Bo Lu, Univ. of Florida College of Medicine (United States); Guanghui Lan, Univ. of Florida (United States)

Image quality of Four dimensional Cone-Beam Computer-Tomography (CBCT) is severely impaired by highly insufficient amount of projection data available for each phase. Therefore, making good use of limited projection data is crucial to solve this problem. Noticing that usually only a portion of the images is affected by motion, we separate the moving part (different between phases) of the images from the static part (identical among all phases) with the help of prior image reconstructed using all projection data. Then we update the moving part and the static part of images alternatively through solving minimization problems based on a global (use full projection data) and several local (use projection data for a certain phase) linear systems. In the other word, we rebuild a large over-determined linear system for static part from the original under-determined systems and we reduce the number of unknowns in the original system for each phase as well. As a result, image quality for both static part and moving part are greatly improved and reliable 4D CBCT images are then reconstructed.

9413-77, Session PSWed

Partial volume correction for arterial spin labeling data using spatial-temporal information

Yang Liu, Baojuan Li, Xi Zhang, Linchuan Zhang, Fourth Military Medical Univ. (China); Zhengrong Liang, The State Univ. of New York (United States); Hongbing Lu, Fourth Military Medical Univ. (China)

Arterial spin labeling (ASL) provides a noninvasive measurement of cerebral blood flow (CBF). Due to relatively low spatial resolution, the accuracy of CBF measurement is affected by the partial volume (PV) effect. In ASL sequence, generally multiple scans of perfusion image pairs are acquired temporally to improve the signal to noise ratio. While several spatial PV correction methods have been proposed for the simple averaging of pair-difference images, the perfusion information of gray matter and white matter existed in multiple image pairs was totally ignored. In this study, a statistical model of perfusion mixtures inside each voxel for the 4D ASL sequence is first proposed. To solve the model, a simplified method is proposed, in which the linear regression (LR) method is first used to obtain initial estimates of spatial correction, then an EM (expectation maximization) method is used to obtain accurate estimation using temporal information. The combination of LR and EM method (EM-LR) can effectively utilize the spatial-temporal information of ASL data for PV correction and provide a theoretical solution to estimate the perfusion mixtures. Both simulated and in vivo data were used to evaluate the performance of proposed method, which demonstrated its superiority on PV correction, edge preserving, and noise suppression.

9413-78, Session PSWed

Intensity transform and Wienner filter in measurement of blood flow in arteriography

Polyana F. Nunes, Marcelo Franco, João Batista Filho, Ana Claudia Patrocinio, UFU (Brazil)

Using the angiography examination it is possible to see anomalies in blood vessels and diseases such as stroke, stenosis, bleeding and especially in the diagnosis of encephalic death in comatose vascular individuals. Thus, we see the need to use digital processing techniques to minimize image noise and improve the pixel count of that. For this reason, this work proposes to use filtering techniques such as average filter and enhancement techniques for transformation intensity using the sigmoid function together with the Wiener filter so you can get less noisy images.

9413-79, Session PSWed

Tchebichef moments based nonlocal-means method for despeckling Optical coherence tomography images

Wanying Jiang, Wenqi Xiang, Mingyue Ding, Xuming Zhang, Huazhong Univ. of Science and Technology (China)

Speckle reduction in optical coherence tomography (OCT) images plays an important role in further image analysis. Although numerous despeckling methods, such as the Kuan's filter, the Frost's filter, wavelet based methods, anisotropic diffusion methods, have been proposed for despeckling OCT images, these methods generally tend to provide insufficient speckle suppression or limited detail preservation especially at high speckle corruption because of the insufficient utilization of image information. Different from these denoising methods, the nonlocal means (NLM) method explores nonlocal image self-similarities for image denoising, thereby providing a new method for speckle reduction in OCT images. However, the NLM method determines image self-similarities based on the intensities of noisy pixels, which will degrade its performance in restoring OCT images. To address this problem, the Tchebichef moments based nonlocal means (TNLM) method is proposed for speckle suppression. Distinctively, the TNLM method determines the nonlocal self-similarities of the OCT images by computing the Euclidean distance between Tchebichef moments of two image patches centered at two pixels of interest in the prefiltered image. Due to the superior feature representation capability of Tchebichef moments, the proposed method can utilize more image structural information for the accurate computation of image self-similarities. The experiments on the clinical OCT images indicate that the TNLM method outperforms numerous despeckling methods in that it can suppress speckle noise more effectively while preserving image details better in terms of human vision, and it can provide higher signal-to-noise ratio (SNR), contrast-to-noise ratio (CNR), equivalent number of looks (ENL) and cross correlation (XCOR).

9413-80, Session PSWed

Multi-session complex averaging for high resolution high SNR 3T MR visualization of ex vivo hippocampus and insula

Aymeric Stamm, Boston Children's Hospital (United States) and Harvard Medical School (United States); Jolene Singh, Boston Children's Hospital (United States); Benoit Scherrer, Onur Afacan, Simon K. Warfield, Boston Children's Hospital (United States) and Harvard Medical School (United States)

To understand the functional specialization of the human brain it is necessary to visualize sub-millimeter structures. However, obtaining quality MR images with both high resolution and optimal contrast presents significant challenges. First, spatial resolution is constrained by scan duration and hardware (i.e. gradient and field strength limits). Furthermore, there is a trade-off between increasing spatial resolution and maximizing signal-to-noise ratio (SNR), which is necessary for obtaining sufficient contrast between the gray matter and white matter.

Previous imaging studies employed repeated imaging and magnitude averaging to compensate for the loss of SNR in high resolution image acquisition (Oros-Peusquens 2010). Magnitude averaging, however, is susceptible to the confounding effects of noise in low SNR regions because magnitude signals follow from a non-linear combination of Gaussian signals, yielding a non-Gaussian signal, whereas arithmetic mean is intimately related to Gaussian variables. In contrast, complex averaging, which requires repeated acquisition of phase and magnitude output images, enables noise cancellation in regions of low SNR, such as the deep brain structures and sulci (Oros-Peusquens 2010).

Here we consider the mathematical properties of magnitude and complex averaging methods and implement complex averaging over multiple sessions to optimize the results of high resolution ex vivo whole brain imaging. The robust procedure we report here applies complex averaging with (1) phase drift correction and a scheme for handling phase outliers because phase images are much more sensitive to artifacts than conventional magnitude images and (2) multi-session compatibility because high resolution structural imaging and ex vivo diffusion imaging at high b-values require long scan durations and trade high spatial resolution for lower signal-to-noise ratio. Our results suggest that multi-session complex averaging is superior to magnitude averaging for high resolution and maximal SNR 3T MR visualization of hippocampus and insular cortex in ex vivo whole brain. This multi-session imaging protocol can be adapted to achieve unprecedented spatial resolution with enhanced SNR and optimal contrast for delineation of key functional areas of interest, such as the hippocampus and thalamus, as part of presurgical planning or post-mortem examination of deep brain structures.

9413-81, Session PSWed

Total variation based image deconvolution for extended depth-of-field microscopy images

Frank Hausser, Ingeborg E. Beckers, Ozan Kahraman, Beuth Hochschule für Technik Berlin (Germany); Michael Gierlak, Beuth University of Applied Sciences (Germany)

One approach for a detailed understanding of dynamical cellular processes during drug delivery is the use of functionalized biocompatible nanoparticles and fluorescent markers. An appropriate imaging system has to detect these particles and cells in real time with high lateral resolution in a range of a few 100nm. In a previous study 'Extended depth-of-field' microscopy (EDF microscopy) has been applied to fluorescent beats and tradiscantia stamen hair cells and the concept of real-time imaging has been proved in different microscopic modes [Beckers et al. 2010]. In principle a phase retardation system so as a programmable space light modulator or a static waveplate are incorporated in the light path and modulate the wavefront of light. Hence the focal ellipsoid is smeared out and images seem to be blurred in a first step. An image restoration by deconvolution using the known point-spread-function (PSF) of the optical system is necessary to achieve sharp microscopic images of an extended depth-of-field.

Here we focus on the investigation and optimization of deconvolution algorithms to solve this restoration problem satisfactorily. This inverse problem is challenging due to presence of Poisson distributed noise and Gaussian noise, and since the PSF used for deconvolution exactly fits in just one plane within the object. We use non linear Total Variation based image restoration techniques, where different types of noise can be treated properly. Various algorithms are evaluated for artificially generated images as well as for more realistic images of prostate cancer cells and fluorescent beads.

9413-82, Session PSWed

Beyond Frangi: an improved multiscale vesselness filter

Tim Jerman, Franjo Pernuš, Boštjan Likar, Ziga Spiclin, Univ. of Ljubljana (Slovenia)

Vascular diseases are among the top three causes of death in the developed countries. Effective diagnosis of vascular pathologies from 2D and 3D angiographic images is therefore very important and usually relies on segmentation and visualization of vascular structures. To enhance the vascular structures prior to their segmentation and visualization, and also suppress non-vascular structures and image noise, the vessel enhancement filters are used extensively. Even though several vessel enhancement filters were proposed in the past, the responses of these filters are typically not uniform between vessels of different radii and, compared to the response in the central part of vessels, their response is lower at vessels' edges and bifurcations. In this paper, we propose a novel vessel enhancement filter based on ratio of multiscale Hessian eigenvalues, which yields a close-to-uniform response in all vascular structures and accurately enhances the border between the vascular structures and the background. The proposed and four state-of-the-art vessel enhancement filters were evaluated and compared on a 3D synthetic image containing tubular structures and a clinical dataset of 15 cerebral 3D digitally subtracted angiograms with manual expert segmentations. The evaluation was based on quantitative metrics of segmentation performance, computed as area under the precision-recall curve, signal-to-noise ratio of the vessel enhancement and the response uniformity within vascular structures. The proposed filter achieved the best scores in all three metrics and can thus be used to further improve the performance of existing or encourage the development of more advanced vessel segmentation and visualization methods.

9413-83, Session PSWed

High performance 3D adaptive filtering for DSP based portable medical imaging systems

Olivier Bockenbach, TechGmbh.Com (Germany); Murtaza Ali, Texas Instruments Inc. (United States); Ian Wainwright, ContextVision AB (Sweden); Mark Nadeski, Texas Instruments Inc. (United States)

Portable medical imaging devices have proven valuable for emergency medical services both in the field and hospital environments and are becoming more prevalent in clinical settings where the use of larger imaging machines is impractical. They also face limitations driven by these features. Despite their constraints on power, size and cost, portable imaging devices must still deliver high quality images.

3D adaptive filtering is one of the most advanced techniques aimed at noise reduction and feature enhancement, but is computationally very demanding and hence often not able to run with sufficient performance on a portable platform.

In recent years, advanced multicore digital signal processors (DSP) have been developed that attain high processing performance while maintaining low levels of power dissipation. These processors enable the implementation of complex algorithms on a portable platform.

In this study, the performance of a 3D adaptive filtering algorithm on a DSP is investigated. The performance is assessed by filtering a volume of size 512x256x128 voxels sampled at a pace of 10 MVoxels/sec with an Ultrasound 3D probe. Relative performance and power is addressed between a reference PC (Quad Core CPU) and a TMS320C6678 DSP from Texas Instruments.

9413-84, Session PSWed

Directional denoising and line enhancement for device segmentation in real time fluoroscopic imaging

Martin G. Wagner, Univ. of Wisconsin-Madison (United States); Kevin L. Royalty, Siemens Medical Solutions USA, Inc. (United States) and Univ. of Wisconsin-Madison (United States); Erick L. Oberstar, Charles M. Strother, Charles A. Mistretta, Univ. of Wisconsin-Madison (United States)

Purpose: The purpose of this work is to improve the segmentation of interventional devices (e.g. guidewires) in fluoroscopic images. This is required for the real time 3D reconstruction from two angiographic views where noise can cause severe reconstruction artifacts and incomplete reconstruction. The proposed method reduces the noise while enhancing the thin line structures of the device in images with subtracted background.

Methods: A two-step approach is presented here. The first step estimates, for each pixel and a given number of directions, a measure for the probability that the point is part of a line segment in the corresponding direction.

This can be done efficiently using binary masks. In the second step, a directional filter kernel is applied for pixel that are assumed to be part of a line. For all other pixels a mean filter is used.

Results: The proposed algorithm was able to achieve an average contrast to noise ratio (CNR) of 6.3 compared to the bilateral filter with 5.8. For the device segmentation using global thresholding the number of missing or wrong pixels is reduced to 25 % compared to 40 % using the bilateral approach.

Conclusion: The proposed algorithm is a simple and efficient approach, which can easily be parallelized for the use on modern graphics processing units. It improves the segmentation results of the device compared to other denoising methods, and therefore reduces artifacts and increases the quality of the reconstruction without increasing the delay in real time applications notably.

9413-85, Session PSWed

Trade-off between speed and performance for colorectal endoscopic NBI image classification

Shoji Sonoyama, Tsubasa Hirakawa, Toru Tamaki, Bisser Raytchev, Kazufumi Kaneda, Tetsushi Koide, Yoko Kominami, Hiroshima Univ. (Japan); Shigeto Yoshida, Hiroshima Univ. Hospital (Japan); Shinji Tanaka, Hiroshima Univ. (Japan)

This paper investigates a trade-off between computation time and recognition rate of local descriptor-based recognition for colorectal endoscopic NBI image classification. Recent recognition methods using descriptors have been successfully applied to medical image classification. The accuracy of these methods might depend on the quality of vector quantization (VQ) and encoding of descriptors, however an accurate quantization takes long time. This paper reports how a simple sampling strategy affects performances with different encoding methods. First, we extract 7.7 million local descriptors from training images of a dataset of 908 NBI endoscopic images (359 of Type A, hyperplasia; 462 of Type B, tubular adenoma; and 87 of Type C3, carcinoma). Second, we randomly choose a subset of between 7.7M and 19K descriptors for VQ. Third, we use three encoding methods (BoVW, VLAD, and Fisher vector) with different number of descriptors. Linear SVM is used for recognition. The computation time for VQ was drastically reduced by the factor of 100, while peak performance was retained. The performance improved roughly by 2% when

more descriptors were used for encoding. Performances with descriptors extracted every pixel ("grid1") or every 2 pixels ("grid2") are similar, while the computation time is very different; grid2 is 5 to 30 times faster than grid1. The primary finding of this paper is twofold. First, recent encoding methods such as VLAD and Fisher vector are as insensitive to the quality of VQ as BoVW. Second, there exits a good trade-off between computation time and performance in encoding descriptors.

9413-86, Session PSWed

Automatic localization of vertebrae based on convolutional neural networks

Wei Shen, Institute of Automation (China); Feng Yang, Beijing Jiaotong Univ. (China); Wei Mu, Caiyun Yang, Xin Yang, Jie Tian, Institute of Automation (China)

Localization of the spine is of importance in many medical applications. For example, the spine can serve as the landmark in image registration. It can also provide a reference coordinate system to facilitate the localization of other organs in the chest. Since the localization of the spine is based on that of the vertebrae which compose the spine, the accuracy of the vertebrae localization becomes very critical. In this paper, we propose a new vertebrae localization method using convolutional neural networks (CNNs). The main advantage of the proposed method is the removal of hand-crafted features. Firstly, we construct two training sets to train two CNNs that share the same architecture. One is used to distinguish the vertebrae from other structures in the chest, and the other is aimed at detecting the centers of the vertebrae. The architecture contains two convolutional layers, either of which is followed by a max-pooling layer. Then the output feature vector from the max-pooling layer is fed into a multilayer perceptron (MLP) classifier which has one hidden layer. Experiments were performed on ten chest CT images. We used leave-one-out strategy to train and test the proposed method. Quantitative comparison between the predict centers and ground truth shows that our convolutional neural networks can achieve promising localization accuracy without hand-crafted features.

9413-87, Session PSWed

Detection of Anomaly In Human Retina using Laplacian Eigenmaps and Vectorized Matched Filtering

Karamatou A. Yacoubou Djima, Lucia Simonelli, Univ. of Maryland, College Park (United States); Denise Cunningham, National Institute of Health (United States); Wojciech Czaja, Univ. of Maryland, College Park (United States)

Age-related Macular Degeneration (AMD) is the leading cause of blindness in elderly patients in industrial- ized nations. Currently, the earliest clinically observable sign of retinal pigment epithelium dysfunction, the cause of AMD, is color fundus deposits known as drusen. Epidemiological studies have found that drusen increases in number and size with age and that larger, irregularly shaped, perifoveal drusen (soft) confer the greatest risk for progression to advanced AMD. Currently, pathologists manually classify drusen based on size and shape, but there is a growing interest in automated analysis tools. In our work, we use autofluorescent data provided by the National Institute of Health (NIH) to detect macular degeneration in early stages in the hopes of tracking its progression.

In previous work, macular anomalies has be detected automatically through a multiscale analysis procedure such as wavelet analysis or dimensionality reduction followed by some classification algorithm, e.g., Support Vector Machine, to capture the drusen locations. The novel method that we propose is a vectorized matched filtering-based algorithm combined with a Laplacian Eigenmaps (LE) algorithm, a nonlinear dimensionality reduction technique with locality preserving properties, for more accurate detection

of reticular drusen. By applying LE, we are able to first represent the data in the form of eigenimages, some of which accentuate the visibility of drusen. We pick significant eigenimages and proceed with an algorithm based on matched filtering to classify the drusen across all of these eigenimages simultaneously. Our preliminary results show that this methodology proves effective in detecting drusen centers.

9413-88, Session PSWed

Direct volume estimation without segmentation

Xiantong Zhen, Western Univ. (Canada); Zhijie Wang, GE Healthcare (Canada); Ali Islam, St. Joseph's Health Care London (Canada); Mousumi Bhaduri, Ian Chan, London Health Sciences Ctr. (Canada); Shuo Li, GE Healthcare (Canada)

Volume estimation plays an important role in clinical diagnosis. For example, cardiac ventricular volumes including left ventricle (LV) and right ventricle (RV) are important clinical indicators of cardiac functions. Accurate and automatic estimation of the ventricular volumes is essential to the assessment of cardiac functions and diagnosis of heart diseases. Conventional methods are dependent on an intermediate segmentation step which is obtained either manually or automatically. However, manual segmentation is extremely time-consuming, subjective and highly non-reproducible; automatic segmentation is still challenging, computationally expensive, and completely unsolved for the RV.

Towards accurate and efficient direct volume estimation, our group has been researching on learning based methods without segmentation by leveraging state-of-the-art machine learning techniques. Our direct estimation methods remove the accessional step of segmentation and can naturally deal with various volume estimation tasks. Moreover, they are extremely flexible to be used for volume estimation of either joint bi-ventricles (LV and RV) or individual LV/RV. We comparatively study the performance of direct methods on cardiac ventricular volume estimation by comparing with segmentation based methods. Experimental results show that direct estimation methods provide more accurate estimation of cardiac ventricular volumes than segmentation based methods. This indicates that direct estimation methods not only provide a convenient and mature clinical tool for cardiac volume estimation but also enables diagnosis of cardiac diseases to be conducted in a more efficient and reliable way.

9413-89, Session PSWed

Spot counting on fluorescence in situ hybridization in suspension images using Gaussian mixture model

Sijia Liu, Ruhan Sa, Univ. at Buffalo (United States); Orla Maguire, Hans Minderman, Roswell Park Cancer Institute (United States); Vipin Chaudhary, Univ. at Buffalo (United States)

Cytogenetic abnormalities are important diagnostic and prognostic criteria for acute myeloid leukemia (AML). Karyotyping and Fluorescent In Situ Hybridization (FISH), are the conventional methods by which these abnormalities are detected. The sensitivity of these microscopy-based methods is limited by the abundance of the abnormal cells in the samples, and therefore these analyses are commonly not applicable to minimal residual disease stages. A flow cytometry-based

imaging approach for FISH in suspension (FISH-IS) was established that enables the automated analysis of several log-magnitude higher number of cells compared to the microscopy-based approaches. The collected images are 2-D projections of a 3-D cell in suspension. Therefore, the rotational positioning of a cell relative to the camera can lead to an

inadvertent overlap of spot-like hybridization sites. In addition, segregation

of a single hybridization site into two or three derivate smaller and dimmer spots can occur all leading to discordance between spot count and ploidy. As a solution of counting error overlapping spots, in this study, a Gaussian Mixture Model (GMM) kernel density estimation based classification method is proposed. The Akaike information criterion (AIC) and Bayesian information criterion (BIC) of GMM are used as global image features of this classification method. Via Random Forest classifier, the result shows that the proposed method is able to detect closely overlapping spots which cannot be separated by existing image segmentation based spot detection methods. The estimation of Gaussian kernels can also be used to provide an accurate position information of detected spots.

9413-90, Session PSWed

Automatic detection of endothelial cells in 3D angiogenic sprouts from experimental phase contrast images

MengMeng Wang, Nanyang Technological Univ. (Singapore); Lee-Ling S. Ong, SMART-Singapore MIT Alliance for Research & Technology (Singapore); Justin Dauwels, Nanyang Technological Univ. (Singapore); Harry Asada, Massachusetts Institute of Technology (United States)

Cell migration studies in 3D environment become more popular, as cell behaviors in 3D are more similar to the behaviors of cells in a living organism (in vivo). We focus on the 3D angiogenic sprouting in microfluidic devices, where Endothelial Cells (ECs) burrow into the gel matrix and form solid lumen vessels. Phase contrast microscopy is used for long-term observation of the unlabeled ECs in the microfluidic devices. Two template matching based approaches are proposed to automatically detect the unlabeled ECs in the angiogenic sprouts from the acquired experimental phase contrast images. Cell and non-cell templates are obtained from the phase contrast images as the training data. The first approach applies Partial Least Square Regression (PLSR) to find the discriminative features and their corresponding weight to distinguish cells and non-cells. Whereas the second approach relies on Principal Component Analysis (PCA) to reduce the template feature dimension and Support Vector Machine (SVM) to find their corresponding weight. Through a sliding window manner, the cells in the test images are detected. We then validate the detection accuracy by comparing the results with the same images acquired with a confocal microscope after cells are fixed and their nuclei are stained. More accurate numerical results are obtained for PLSR compared to PCA & SVM for cell detection. Automatic cell detection will aid in the understanding of cell migration in 3D environment and in turn result in a better understanding of angiogenesis.

9413-91, Session PSWed

Method for accurate sizing of pulmonary vessels from 3D medical images

Walter G. O'Dell, Univ. of Florida (United States)

Detailed characterization of vascular anatomy, in particular the quantification of changes in the distribution of vessel sizes and of vascular pruning, is essential for the diagnosis and management of a variety of pulmonary vascular diseases and for the care of cancer survivors who have received radiation to the thorax. Clinical estimates of vessel radii are typically based on setting a pixel intensity threshold and counting how many "On" pixels are present across the vessel cross-section. A more objective approach introduced recently involves fitting the image with a library of spherical Gaussian filters and utilizing the size of the best matching filter as the estimate of vessel diameter. However, both these approaches have significant accuracy limitations including mis-match between a Gaussian intensity distribution and that of real vessels. Here we introduce and demonstrate a novel approach for accurate vessel sizing

using 3D appearance models of a tubular structure along a curvilinear trajectory in 3D space. The vessel branch trajectories are represented with cubic Hermite splines and the tubular branch surfaces represented as a finite element surface mesh. An iterative parameter adjustment scheme is employed to optimally match the appearance models to a patient's chest X-ray computed tomography (CT) scan to generate estimates for branch radii and trajectories with sub-pixel resolution. The method is demonstrated on pulmonary vasculature in an adult human CT scan, and on 2D simulated test cases.

9413-92, Session PSWed

Optimal reinforcement of training dataset in supervised landmark-based segmentation

Bulat Ibragimov, Bo?tjan Likar, Franjo Pernu?, Univ. of Ljubljana (Slovenia); Toma? Vrtovec, Univ of Ljubljana (Slovenia)

During the last couple of decades, the development of computerized image segmentation shifted from unsupervised to supervised methods, which made segmentation results more accurate and robust. However, the main disadvantage of supervised segmentation is a need for a manually image annotation, which is time consuming and subjected to human error. To reduce the need for manual annotation, we propose a novel learning approach for training dataset reinforcement. The proposed approach is focused on landmark-based segmentation and analyzes the representatives of detected landmarks and inclusion of these landmarks as samples into the landmark training dataset. The problem is formulated as a non-linear optimization, where the solution is a vector of weighting factors that measure how reliable are the detected landmarks. More reliable detected landmarks are included into the training procedure with higher weighting factors, whereas less reliable detected landmarks are included with lower weighting factors. The approach will be integrated into the landmark-based game-theoretic segmentation framework and validated against problems of lung fields segmentation from chest radiograms and lumbar vertebrae segmentation from computed tomography images.

9413-93, Session PSWed

Freehand 3D ultrasound reconstruction based on global filling model

Weijian Cong, Jian Yang, Danni Ai, Leiya Ma, Yue Liu, Yongtian Wang, Beijing Institute of Technology (China)

This work proposes a novel method for accurate 3D reconstruction of ultrasound volume from a series of 2D ultrasound acquisitions. First, all pixels in the B-model ultrasound slices are traversed, and the vacant voxels are assigned by their neighboring voxels according to the presupposed distance threshold. The intensity value of the vacant voxel is interpolated by the distance weight of every neighboring voxels. Second, all the vacant regions are counted and separated in the ultrasound volume, for which the assignment weights of all edge voxel of vacant regions are calculated. Then, the best matching patch is optimized by searching the largest weight assignment. The vacant voxels are iteratively assigned by the best matching patches, and the assignment weights of the vacant regions are updated simultaneously. The process continues until there is no vacant voxel. Experimental results demonstrate the effectiveness and robustness of the proposed method for the reconstruction of ultrasound volume.

9413-94, Session PSWed

Piecewise recognition of bone skeleton profiles via an iterative Hough transform approach without re-voting

Anna Maria Massone, CNR (Italy); Giorgio Ricca, Univ degli Studi di Genova (Italy); Mauro C. Beltrametti, Michele Piana, Univ. degli Studi di Genova (Italy)

The Hough transform is a well known pattern recognition technique to detect features in images when specified in some parametric form. Many bone shapes in the human skeleton are characterized by profiles that can be associated to equations of algebraic curves. By means of the Hough transform, it is then possible to associate an equation to a specific bone profile.

However, many recognition tasks in real applications require the identification of profiles that cannot be associated to a single curve but are more realistically represented by piecewise defined curves. As a consequence, the identification of bone profiles in the human skeleton requires a method to assign an appropriate piece of curve to a specific portion of the real skeleton profile. Therefore, an approximation of the whole district shape can be obtained by using an iterative approach to Hough transform, in order to iteratively approximate different parts of the same bone profile with different curves.

To realize such a procedure, one can eliminate those points in the profile that have been already recognized and iteratively re-apply the method on the remaining set of points. However, this procedure is computationally expensive and therefore we introduce a layered accumulator matrix that allows us to discard the contribution of some points in the voting procedure without re-voting. This way, we provide an efficient procedure for describing the profile of a bone in X-ray CT images as a collection of different but continuously attached curves without dramatically increasing the computational cost of the algorithm.

9413-95, Session PSWed

A novel Hessian based algorithm for kidney glomeruli detection in 3D MRI

Min Zhang, Mayo Clinic Arizona (United States) and Arizona State Univ. (United States); Teresa Wu, Arizona State Univ. (United States); Kevin M. Bennett, Univ. of Hawai'i at Manoa (United States)

The glomeruli of the kidney perform the key role of blood filtration and the number of glomeruli in a kidney is correlated with susceptibility to chronic kidney disease and chronic cardiovascular disease, inspiring the new technology such as magnetic resonance imaging (MRI) to measure kidney morphology in vivo. However, there is currently a lack of computationally efficient techniques to perform fast, reliable and accurate counts of glomeruli in MR images due to the challenges of acquisition noise, partial volume effect (the mixture of several tissue signals in a voxel) and bias field (spatial intensity inhomogeneity). Such challenges are becoming even severe since the glomeruli are very small (in our case, a MRI image is ~16 million voxels, each glomerulus is in the size of 8~20 voxels) and the number of glomeruli is very large. To fill this gap, we have developed an efficient Hessian based Difference of Gaussians (HDoG) detector to identify the glomeruli on 3D rat MR images. Like most imaging detectors, an image is first smoothed via DoG. Hessian analysis is then launched to identify the single optimal scale based on which a pre-segmentation is conducted. Another advantage of the Hessian process is that it is capable to delineate the glomeruli. As a result, regional features can be retrieved. These features enable the unsupervised clustering algorithm for post pruning for further improved identification. The experimental result shows that, statistically, Hessian based DoG can identify similar number of glomeruli as our maceration counts and stereology counts.

9413-96, Session PSWed

Detection method of visible and invisible nipples on digital breast tomosynthesis

Seung-Hoon Chae, Ji-Wook Jeong, Sooyeul Lee, Electronics and Telecommunications Research Institute (Korea, Republic of); Eun Young Chae M.D., Hak Hee Kim M.D., Asan Medical Ctr. (Korea, Republic of); Young-Wook Choi, Korea Electrotechnology Research Institute (Korea, Republic of)

Digital Breast Tomosynthesis(DBT) with 3D breast image can improve detection sensitivity of breast cancer more than 2D mammogram on dense breast. The nipple location information is needed to analyze DBT. The nipple location is invaluable information in registration and as a reference point for classifying micro-calcification clusters. The nipple detection of breast must be possible to detect visible and invisible nipple of breast. The detection method of visible nipple using shape information of nipple is simple and highly efficient. However, it is difficult to detect invisible nipple because it doesn't have prominent shape. Mammary glands in breast connect nipple, anatomically. The nipple location is detected though to analyze location of mammary glands in breast. In this paper, therefore, we propose a method to detect the nipple on a breast, which has a visible or invisible nipple using shape of breast and mammary glands, respectively.

9413-97, Session PSWed

Semi-automatic delineation of the spino-laminar junction curve on lateral x-ray radiographs of the cervical spine

Benjamin Narang, Ecole Nationale Supérieure de Techniques Avancées (France); Michael Phillips, City Univ. London (United Kingdom); Karen Knapp, Univ. of Exeter (United Kingdom); Andy Appelboam, Royal Devon & Exeter NHS Foundation Trust (United Kingdom); Adam Reuben, Royal Devon and Exeter NHS Foundation Trust (United Kingdom); Greg Slabaugh, City Univ. London (United Kingdom)

Assessment of the cervical spine using x-ray radiography is an important task when providing emergency room care to trauma patients. In clinical practice, a physician will inspect the alignment of the cervical spine vertebrae by mentally tracing three alignment curves along the anterior and posterior sides of the cervical vertebral bodies, as well as one along the spinolaminar junction. In this paper, we propose an algorithm to semi-automatically delineate the spinolaminar junction curve, given a single reference point and the corners of each vertebrae. From the reference point, our method extracts a region of interest, and performs template matching using normalized cross-correlation to find matching regions along the spinolaminar junction. Matching points are then fit to a third order spline, producing an interpolating curve. Experimental results demonstrate promising results, on average producing a modified Hausdorff distance of 1.8 mm, validated on a dataset consisting of 29 patients including those with degenerative change, retrolisthesis, and fracture.

DESCRIPTION OF PURPOSE: Cervical spine injuries (CSIs) occur in approximately 4.3% of all trauma patients [1]. Evaluation of the cervical spine x-ray is often a pressing diagnostic challenge for emergency physicians, as up to 20% of CSI patients suffer extension of their injuries due to delayed or missed diagnosis [2], which can have severe consequences to the patient. The emergency room physician use a lateral x-ray to study the alignment of the cervical spine column by mentally drawing curves along the spinal column, including the spinolaminar junction curve, which follows the interior edge of the spinous processes.

In this paper, we present a semi-automatic approach to delineate the spinolaminar junction curve. Given a user-supplied click point on the spinolaminar junction, and a set of vertebral body corners, for each vertebra we extract a 2D region of interest and perform template matching using normalized cross-correlation to find a matching point on the spinolaminar junction. The detected points are fit to a third order spline, and overlaid on the image to provide support to the physician reading the image. Experimental results demonstrate promising performance of the proposed method, with a good agreement with curves produced manually by an expert radiographer.

DISCUSSION AND CONCLUSION: While further experimentation is ongoing, our experiments demonstrate the promise of this method to delineate the spinolaminar junction in lateral x-ray images. A mean MHD of 1.8 mm provides very good performance.

Future work will seek to automate the user click point so that the technique is fully automatic, and perform an observer study to determine the degree to which the spinolaminar junction curve overlay is helpful for the emergency room physician in assessing a x-ray image of the cervical spine.

REFERENCES

[1] Benjelloun, M., Mahmoudi, S., and Lecron, F., "Computed tomography versus plain radiography to screen for cervical spine injury: A meta-analysis," J. of Trauma 58(8) (2005).

[2] Davis, J. W., Phreaner, D. L., Hoyt, D. B., and Mackersie, R. C., "The etiology of missed cervical spine injuries," Journal of Trauma-Injury Infection & Critical Care: (March 1993).

[3] Benjelloun, M., Mahmoudi, S., and Lecron, F., "A framework of vertebra segmentation using the active shape model-based approach," International Journal of Biomedical Imaging (2011).

[4] Xu, X., Hao, H.-W., Xu-Cheng, Y., Liu, N., and Shafin, S., "Automatic Segmentation of Cervical Vertebrae in X-ray Images," in [Intl. Joint Conf. on Neural Networks], (2012).

[5] Tsai, D.-M. and Lin, C.-T., "Fast normalized cross correlation for defect detection," Pattern Recognition Letters 24, 2625–2631 (November 2003).

[6] Vrtovec, T., Pernus, F., and Likar, B., "A review of methods for quantitative evaluation of spinal curvature," European Spine Journal 18(5) (2009).

9413-98, Session PSWed

Evaluating MRI based vascular wall motion as a biomarker of Fontan hemodynamic performance

Haifa Hong M.D., Shanghai Children's Medical Center, Shanghai Jiaotong Univ. School of Medicine (China); Prahlad G. Menon, SYS-CMU Joint Institute of Engineering (United States) and The Univ. of Texas at San Antonio (United States) and Univ. of Pittsburgh (United States)

The Fontan procedure is a palliative surgery for complex congenital heart disease wherein the final stage of vascular reconstruction involves creation of pathways to divert blood from the superior & inferior vena cavae (SV, IVC) into the pulmonary arteries (PA) while bypassing the right ventricle. Evaluation of hemodynamics at of the resulting vascular construction (viz. the total cavopulmonary connection - TCPC) to ensure minimal energy loss owing to collision of IVC and SVC flow-streams as well as optimal flow distributions from the vena cavae to the left & right PA is paramount for optimal surgical outcomes. However, such hemodynamic evaluation requires high-performance computational fluid dynamics (CFD) which limits applicability to patient management in the clinic. In this study, we establish correlations between vascular wall motion and pre-computed hemodynamic criteria from CFD modeling in 5 unique Fontan surgical connections which were segmented at each cardiac phase from cine cardiovascular MRI. Cumulative wall displacement of the Fontan conduit / connection from IVC to PA was examined over 20 cardiac phases gated from the start of ventricular systole, using a signed, regional Hausdorff distance metric, at each segmented surface in the time-series. Synchronized with the beating of the heart, some patient-specific connections were observed to experience a lateral displacement of their centroid evidenced by a positive HD (outward)

on one side and negative HD (inward) on the diametrically opposite side of the conduit, in addition to independent contraction & dilation function. To focus on diametric variation of the conduit while discounting side-to-side motion, the difference between the absolute values of the conduit-averaged positive HD (outward) and negative HD (inward) contraction was analyzed. This metric was concordant with observations of phase-to-phase conduit displacement, validating the approach. Our pilot study reveals the existence of weak correlations between maximum conduit-averaged expansion over the cardiac cycle and the diametric offset between the axis of the IVC and SVC (R2=0.1316, P=0.5484) – a known factor correlated with both TCPC energy loss (R2=0.52, P=0.17) and IVC-to-PA flow distribution (R2=0.5731, P=0.1384) in our study cohort. This warrants further investigation of vascular wall motion metric in a larger patient cohort, to establish stronger statistical correlations between Fontan wall function and hemodynamic performance.

9413-99, Session PSWed

Evaluation of COPD's diaphragm motion extracted from 4D-MRI

Windra Swastika, Chiba Univ. (Japan); Yoshitada Masuda, Naoko Kawata, Koji Matsumoto M.D., Toshio Suzuki M.D., Ken Iesato M.D., Yuji Tada M.D., Toshihiko Sugiura M.D., Nobuhiro Tanabe, Koichiro Tatsumi M.D., Chiba University Hospital (Japan); Takashi Ohnishi, Center for Frontier Medical Engineering (Japan); Hideaki Haneishi, Ctr. for Frontier Medical Engineering (Japan)

We have developed a method called intersection profile method to construct a 4D-MRI (3D+time) from time-series of 2D-MRI. The basic idea is to find the best matching of the intersection profile from the time series of 2D-MRI in sagittal plane (navigator slice) and time series of 2D-MRI in coronal plane (data slice). In this study, we use 4D-MRI to semi-automatically extract the right diaphragm motion of 17 subjects (8 healthy subjects and 9 COPD patients).

The diaphragm motion is then evaluated quantitatively by calculating the displacement of each subjects and normalized it. We also generate phase-length map to view and locate paradoxical motion of the COPD patients.

The quantitative results of the normalized displacement shows that COPD patients tend to have smaller displacement compared to healthy subjects. The average normalized displacement of total 8 COPD patients is 9.4mm and the average of normalized displacement of 8 healthy volunteers is 15.3mm. The generated phase-length maps show that not all of the COPD patients have paradoxical motion, however if it has paradoxical motion, the phase-length map is able to locate where does it occur.

9413-100, Session PSWed

Calculation of brain atrophy using computed tomography and a new atrophy measurement tool

Abdullah Bin Zahid, Artem Mikheev, Il Yang, Uzma Samadani, Henry H. Rusinek, New York Univ. Langone Medical Ctr. (United States)

Purpose: To determine if brain atrophy can be calculated by performing volumetric analysis on conventional computed tomography (CT) scans in spite of relatively low contrast for this modality.

Materials & Method: CTs for 73 patients from the local Veteran Affairs database were selected. Exclusion criteria: AD, NPH, tumor, and alcohol abuse. Protocol: conventional clinical acquisition (Toshiba; helical, 120 kVp, X-ray tube current 300mA, slice thickness 3-5mm). Locally developed, automatic algorithm was used to segment intracranial cavity (ICC) using (a) white matter seed (b) constrained growth, limited by inner skull layer and (c) topological connectivity. ICC was further segmented into CSF and brain

parenchyma using a threshold of 16 Hu.

Results: Age distribution: 25–95yrs.; (Mean 67±17.5yrs.). Significant correlation was found between age and CSF/ICC(r=0.695, p<0.01 2-tailed). A quadratic model(y=0.06–0.001x+2.56x10-5x2; where y=CSF/ICC and x=age) was a better fit to data(r=0.716, p<0.01). This is in agreement with MRI literature. For example, Smith et al (1) found annual CSF/ICC increase in 58 – 94.5 y.o. individuals to be 0.2%/year, whereas our data, restricted to the same age group yield 0.3%/year(0.2–0.4%/yrs. 95%C.I.). Slightly increased atrophy among elderly VA patients is attributable to the presence of other comorbidities.

Conclusion: Brain atrophy can be reliably calculated using automated software and conventional CT. Compared to MRI, CT is more widely available, cheaper, and less affected by head motion due to ~100 times shorter scan time. Work is in progress to improve measurement precision, possibly leading to assessment of longitudinal changes within the patient.

9413-101, Session PSWed

Automated detection of periventricular veins on 7 T brain MRI

Hugo J. Kuijf, Image Sciences Institute, Univ. Medical Ctr. Utrecht (Netherlands); Willem Bouvy, Utrecht Brain Ctr. Rudolf Magnus, Univ. Medical Ctr. Utrecht (Netherlands); Jaco J. M. Zwanenburg, Max A. Viergever, Image Sciences Institute (Netherlands); Geert Jan Biessels, Univ. Medical Ctr. Utrecht (Netherlands); Koen L. Vincken, Image Sciences Institute (Netherlands)

Cerebral small vessel disease is common in elderly persons and a leading cause of cognitive decline, dementia, and acute stroke. With the introduction of ultra-high field strength 7 T MRI, it is possible to visualize small vessels in the brain. In this work, a proof-of-principle study is conducted to assess the feasibility of automatically detecting periventricular veins.

Periventricular veins are organized in a fan-pattern and drain venous blood from the brain towards the caudate vein of Schlesinger, which is situated along the lateral ventricles. Just outside this vein, a region-of-interest (ROI) through which all periventricular veins must cross is defined. Within this ROI, a combination of the vesselness filter, tubular tracking, and hysteresis thresholding is applied to locate periventricular veins.

All detected locations were evaluated by an expert human observer. The results showed a positive predictive value of 88% and a sensitivity of 95% for detecting periventricular veins.

The proposed method shows good results in detecting periventricular veins in the brain on 7 T MR images. Compared to previous works, that only use a 1D or 2D ROI and limited image processing, our works presents a more comprehensive definition of the ROI, advanced image processing techniques to detect periventricular veins, and a quantitative analysis of the performance. The results of this proof-of-principle study are promising and will be used to assess periventricular veins on 7 T brain MRI.

9413-102, Session PSWed

Automated coronary artery calcium scoring from non-contrast CT using a patient-specific algorithm

Xiaowei Ding, Cedars-Sinai Medical Ctr. (United States) and Univ. of California, Los Angeles (United States); Piotr J. Slomka, Mariana Diaz-Zamudio, Guido Germano, Daniel S. Berman, Cedars-Sinai Medical Ctr. (United States); Demetri Terzopoulos, Univ. of California, Los Angeles (United States); Damini Dey, Cedars-Sinai Medical Ctr. (United States)

Non-contrast cardiac CT is used worldwide to assess coronary artery calcium (CAC), a subclinical marker of coronary atherosclerosis. Manual quantification of regional CAC scores includes identifying candidate regions, followed by thresholding and connected component labeling. We aimed to develop and validate a fully-automated, algorithm for both overall and regional measurement of CAC scores from non-contrast CT using a hybrid multi-atlas registration, active contours and knowledge-based region separation algorithm.

A co-registered segmented CT atlas was created from manually segmented non-contrast CT data from 10 patients (5 men, 5 women) and stored offline. For each patient scan, the heart region, left ventricle, right ventricle, ascending aorta and aortic root are located by multi-atlas registration followed by active contours refinement. Regional coronary artery territories (left anterior descending artery, left circumflex artery and right coronary artery) are separated using a knowledge-based region separation algorithm. Calcifications from these coronary artery territories are detected by region growing at each lesion.

Global and regional Agatston scores and volume scores were calculated in 50 patients. Agatston scores and volume scores calculated by the algorithm and the expert showed excellent correlation (Agatston score: r = 0.97, p < 0.0001, volume score: r = 0.97, p < 0.0001) with no significant differences by comparison of individual data points (Agatston score: p = 0.30, volume score: p = 0.33). The total time was <60 sec on a standard computer. Our results show that fast accurate and automated quantification of CAC scores from non-contrast CT is feasible.

9413-103, Session PSWed

Computational analysis of PET by AIBL (CapAIBL): a cloud-based processing pipeline for the quantification of PET images

Pierrick T. Bourgeat, Vincent Doré, Jurgen Fripp, Australian e-Health Research Ctr. (Australia); Victor L. Villemagne, The Univ. of Melbourne (Australia); Chris Rowe, Austin Hospital (Australia); Olivier Salvado, Australian e-Health Research Ctr. (Australia)

With the advances of PET tracers for B-Amyloid detection in neurodegenerative diseases, there is a great need for unified automated quantification methods. For clinical use, there is a great need for PET-only quantification method, as MR images are not always available. Using CapAIBL (http://milxcloud.csiro.au/capaibl), PET images are uploaded to a cloud based platform where they are spatially normalised to a standard template and quantified. A report containing global as well as local quantification, along with surface projection of the B-Amyloid deposition is automatically generated at the end of the pipeline and emailed to the user. The method has been validated on 6 different tracers against MR-based PET quantification, and was shown to have an overall error of less than 5% for each tracer.

9413-104, Session PSWed

Image-based reconstruction of 3D myocardial infarct geometry for patient specific applications

Eranga Ukwatta, Johns Hopkins Univ. (United States); Martin Rajchl, Robarts Research Institute (Canada); James A. White, Univ. of Calgary (Canada); Farhad Pashakhanloo, Daniel A. Herzka, Elliot McVeigh, Albert C. Lardo, Natalia Trayanova, Fijoy G. Vadakkumpadan, Johns Hopkins Univ. (United States)

Reconstruction of the three-dimensional (3D) geometry of a myocardial infarct from two-dimensional (2D) image slices has important applications in the clinical evaluation and treatment of patients with ischemic cardiomyopathy. However, this reconstruction is challenging because the resolution of common clinical scans used to acquire infarct structure, such as short-axis, late-gadolinium enhanced cardiac magnetic resonance (LGE-CMR) images, is low, especially in the out-of-plane direction. In this study, we propose a novel technique to reconstruct the 3D infarct geometry from low resolution clinical images. Our methodology is based on a function called logarithm of odds (LogOdds), which allows the broader class of linear combinations in the LogOdds vector space as opposed to being limited to only a convex combination in the binary label space. To assess the efficacy of the method, we used high- resolution LGE-CMR images of 36 human hearts in vivo, and 3 canine hearts ex vivo. The infarct was manually segmented in each slice of the acquired images, and the manually segmented data were downsampled to clinical resolution. The method was then applied to the downsampled image slices, and the resulting reconstructions were compared with the manually segmented data. Several existing reconstruction techniques were also implemented, and compared with the proposed method. The results show that the LogOdds method significantly outperforms all the other tested methods in terms of region overlap.

9413-105, Session PSWed

Initial evaluation of a modified dual-energy window scatter correction method for CZT-based gamma cameras for breast SPECT

Steve D. Mann, Martin P. Tornai, Duke Univ. (United States)

Solid state CZT-based gamma cameras for SPECT imaging offer significantly improved energy resolution compared to traditional NaI scintillation detectors. However, the photopeak resolution is often asymmetric due to incomplete charge collection within the detector, resulting in many photopeak events being incorrectly sorted into lower energy bins ("tailing"). These misplaced events can contaminate the true scatter signal, which may negatively impact scatter correction methods that rely on estimates of scatter from the spectra. Additionally, because CZT detectors are array detectors, each individual detector element may exhibit various degrees of tailing. Here, we present a modified dual-energy window scatter correction method that attempts to account for position-dependent effects of incomplete charge collection in the CZT gamma camera of our dedicated breast SPECT-CT system. Point source measurements and geometric phantoms were used to estimate the impact of tailing on the scatter signal and extract a better estimate of the ratio of scatter within two energy windows. To evaluate the method, cylindrical phantoms with and without a separate fillable chamber were scanned to determine the impact on quantification in hot, cold, and uniform background regions. Projections were reconstructed using OSEM, and the results for the traditional and modified scatter correction methods were compared. Results show that while modest reduced quantification accuracy was observed in hot and cold regions of the multi-chamber phantoms, the modified scatter correction method yields up to 8% improved quantification accuracy within uniform background regions and also less added noise compared to the traditional DEW method with global k-value.

9413-106, Session PSWed

Schizophrenia patients differentiation based on MR vascular perfusion and volumetric imaging

Assaf B. Spanier, The Rachel and Selim Benin School of Computer Science and Engineering (Israel) and The Hebrew Univ. of Jerusalem (Israel); Leo Joskowicz, The Rachel and Selim Benin School of Computer Science and

Engineering (Israel) and The Hebrew Univ. of Jerusalem (Israel) and The Edmond & Lily Safra Ctr. for Brain Sciences (Israel); Shay Moshel, David Israeli, Jerusalem Mental Health Ctr., The Hebrew Univ. Hadassah Medical School (Israel)

Candecomp/Parafac Decomposition (CPD) has emerged as a framework for modeling N-way arrays (higher-order matrices). CPD is naturally well suited for the analysis of data sets comprised of observations of a function of multiple discrete indices. In this study we evaluate the prospects of using CPD for modeling MRI brain properties (i.e. brain volume and gray-level) for schizophrenia diagnosis. Taking into account that 3D imaging data consists of millions of pixels per patient, the diagnosis of a schizophrenia patient based on pixel analysis constitutes a methodological challenge (e.g. multiple comparison problem). We show that the CPD could potentially be used as a dimensionality redaction method and discriminator between schizophrenia patients and match control, using the gradient of pre- and post Gd-T1-weighted MRI data, which is strongly correlated with cerebral blood perfusion. Our approach was tested on 68 MRI scans: 40 first-episode schizophrenia patients and 28 matched controls. The CPD subject's score exhibits statistically significant result (P < 0.001). Moreover, the CPD component is not just about statistically significant and dimensionality reduction, but it is also interpretable and meaningful. In the context of diagnosing schizophrenia with MRI, these results suggest that the CPD method could potentially be used to distinguish between schizophrenia patients and matched control.

9413-107, Session PSWed

2D-3D non-rigid registration using thin-plate spline and volume rendering

Jean Young Song, Charles R. Meyer, Univ. of Michigan (United States)

Image registration techniques to merge data from two or more different modalities are rapidly advancing as research on treating diseases diversifies. This is especially the case when 2D projection images from endoscopy or colonoscopy have to be aligned with 3D volumes from MRI or CT for reasons such as navigation in surgery or validating biomarkers for cancer screening. In this paper, we propose a 2D-3D non-rigid image registration using thin-plate splines (TPS) and volume rendering to align projection images from ex vivo 3D MR volumes to in vivo 2D colonoscopy images. Our algorithm starts with computing geometric camera calibration of the colonoscopy camera to rectify images and to find the field of view of the camera. Volume rendering based on ray tracing method is then performed on an MRI data set which is deformed using TPS-based 3D non-rigid geometric transformation. For optimization we used mutual information as similarity metric to compare colonoscopy images with warped/rendered MR projection images. Experiments were performed on synthesized colonoscopy image using optimized 2D ray traced projection images of the MR volume. RMS error of control point locations was below 1mm. The proposed registration technique can further be used to register histology slides or fluorescence microscopy images of adenomatous tissue with colonoscopy images for validation purpose of peptide biomarkers for colonoscopy cancer screening.

9413-108, Session PSWed

Image registration based on the structure tensor of the local phase

Zhang Li, Lucas J. van Vliet, Technische Univ. Delft (Netherlands); Jaap Stoker, Academic Medical Ctr. (Netherlands); Frans M. Vos, Technische Univ. Delft (Netherlands) and Academisch Medisch Centrum (Netherlands)

Image registration of medical images in the presence of severe intra-image signal fluctuations is a challenging task. This paper addresses this problem by introducing a new local structure representation based on the structure tensor of the local phase image. The structure tensor is often used for representing local structure of images and many types of structure tensors can be found in different applications. The boundary tensor combines the responses of edges and corners/junctions in one tensor which shows several advantages compared to other structure tensors (e.g. it prevents multiple responses at junctions). The local phase image is derived from a multi-scale representation of the monogenic signal. In contrast to the intensity image, the local phase image is hardly affected by the aforementioned signal fluctuations. By combining the properties of the structure tensor and local phase, we obtain a structure representation of the image which is insensitive to intra-image signal fluctuations. Similar to tensor reorientation employed in the registration of diffusion tensor MRI data, we reorient the structure tensor during the registration. The structure tensor is only calculated once during the preprocessing stage. Preliminary results have shown that our proposed method can deal with the registration of images hampered by severe intra-image signal fluctuations. The method performs better than other competing image registration methods employing local structure information.

9413-109, Session PSWed

A liver registration method for segmented multi-phase CT images

Shuyue Shi, Rong Yuan, Zhi Sun, Qingguo Xie, Huazhong Univ. of Science and Technology (China)

In order to build high quality geometric models for liver containing vascular system, multi-phase CT series used in a computer–aided diagnosis and surgical planning system aims at liver diseases have to be accurately registered. In this paper we model the segmented liver containing vascular system as a complex shape and propose a two-step registration method. Without any tree modeling for vessel this method can carry out a simultaneous registration for both liver tissue and vascular system inside. Firstly a rigid aligning using vessel as feature is applied on the complex shape model while genetic algorithm is used as the optimization method. Secondly we achieve the elastic shape registration by combine the incremental free form deformation (IFFD) with a modified iterative closest point (ICP) algorithm. Inspired by the concept of demons method, we propose to calculate a fastest diffusion vector (FDV) for each control point on the IFFD lattice to replace the points correspondence needed in ICP iterations. Under the iterative framework of the modified ICP, the optimal solution of control points' displacement in every IFFD level can be obtained efficiently. The method has been quantitatively evaluated on clinical multi-phase CT series.

9413-110, Session PSWed

Non-rigid MRI-TRUS registration in targeted prostate biopsy

Bahram Marami, Robarts Research Institute (Canada); Shahin Sirouspour, McMaster Univ. (Canada); Suha Ghoul, Robarts Research Institute (Canada); Shadi Emami Abarghouei, McMaster Univ. (Canada); Yue Sun, Aaron Fenster, Robarts Research Institute (Canada)

A non-rigid registration method is presented for the alignment of pre-procedural magnetic resonance (MR) images with delineated suspicious regions to intra-procedural 3D transrectal ultrasound (TRUS) images in TRUS-guided prostate biopsy. In the first step, 3D MR and TRUS images are aligned rigidly using six pairs of manually identified approximate matching points on the boundary of the prostate. Then, two 3D image are non-rigidly registered using a finite element method- (FEM-) based linear elastic deformation model. A vector of observation prediction errors at some points of interest within the prostate 3D images is computed using

an intensity-based similarity metric called the modality independent neighborhood descriptor (MIND). The error vector is employed in a classical state estimation framework to estimate prostate deformation between MR and TRUS images. The points of interests are identified using speed-up robust features (SURF) that are scale and rotation-invariant descriptors in MR images. The proposed registration method on 10 sets of prostate MR and US images yielded a target registration error of 1.99±0.83 mm, and 1.97±0.87 mm in the peripheral zone (PZ) and whole gland (WG), respectively, using 68 manually-identified fiducial points. The Dice similarity coefficient (DSC) was 87.9±2.9, 82.3±4.8, 93.0±1.7, and 84.2±6.2 percent for the WG, apex, mid-gland and base of the prostate, respectively. Moreover, the mean absolute distances (MAD) between the WG surfaces in the TRUS and registered MR images was 1.6±0.3 mm. Registration results indicate effectiveness of the proposed method in improving the targeting accuracy in the TRUS-guided prostate biopsy.

9413-111, Session PSWed

Deformable registration of CT and cone-beam CT by local CBCT intensity correction

Seyoun Park, The Johns Hopkins Hospital (United States); William Plishker, IGI Technologies (United States); Raj Shekhar, Children's National Medical Ctr. (United States); Harry Quon, John Wong, The Johns Hopkins Hospital (United States); Junghoon Lee, Johns Hopkins Univ. (United States)

In this paper, we propose a method to accurately register CT to cone-beam CT (CBCT) by iteratively correcting local CBCT intensity. CBCT is a widely used intra-operative imaging modality in image-guided radiotherapy and surgery. A short scan followed by a filtered-backprojection is typically used for CBCT reconstruction. While data on the mid-plane (plane of source-detector rotation) is complete, off-mid-planes undergo different information deficiency and the computed reconstructions are approximate. This causes different reconstruction artifacts at off-mid-planes depending on slice locations, and therefore impedes accurate registration between CT and CBCT. To address this issue, we correct CBCT intensities by matching local intensity histograms slice by slice in conjunction with intensity-based deformable registration. The demons algorithm that is one of robust and efficient deformable registration methods is used to register the CT to the intensity-corrected CBCT. This correction-registration step is repeated until the result image converges. We tested the proposed methods on eight head-and-neck cancer cases and compared its performance with state-of-the-art registration methods. Normalized mutual-information (NMI) was computed as a similarity measure for the performance evaluation. Our method produced overall NMI of 0.586, outperforming existing methods by 4%. Experimental results show that our method is more consistent and roust than existing algorithms, and also computationally efficient with faster convergence.

9413-112, Session PSWed

A fast alignment method for breast MRI follow-up studies using automated breast segmentation and current-prior registration

Lei Wang, Jan Strehlow, Jan Ruehaak, Florian Weiler, Fraunhofer MEVIS (Germany); Yago Diez, Univ. de Girona (Spain); Albert Gubern-Mérida, Radboud Univ. Nijmegen Medical Ctr. (Netherlands); Susanne Diekmann, Hendrik Laue, Horst K. Hahn, Fraunhofer MEVIS (Germany)

In breast cancer screening for high-risk women, follow-up magnetic resonance images (MRI) are acquired with a time interval ranging from several months up to a few years. Prior MRI study provides additional clinical values when examining the current one and thus increases the sensitivity and specificity of screening. To build a spatial correlation between suspicious findings in both current-prior studies, a reliable alignment method between follow-up studies is desirable. However, long time interval, different scanners and imaging protocol, and variant breast compression can result in a large deformation, which challenges the registration process. In this work, we present a fast and robust spatial alignment framework, which combines automated breast segmentation and current-prior registration techniques in a multi-level fashion. First, fully automatic breast segmentation is applied to extract breast masks that are used to obtain an initial affine transform. Then, a non-rigid registration algorithm using normalized gradient field as similarity measure is applied in different level of resolutions. A total of 29 subjects and 58 breast MR images were collected for performance assessment. To evaluate global registration accuracy, the volume overlap and boundary surface distance metrics are calculated, resulting in an average Dice Coefficient (DC) of 0.96 and root mean square distance (RMSD) of 1.61 mm. In addition, to measure local registration accuracy, for each subject a radiologist annotated 10 pairs of markers in current and prior studies representing corresponding anatomical locations. The average distance error of marker pairs was 10.86 mm.

9413-113, Session PSWed

Image registration using stationary velocity fields parameterized by norm-minimizing Wendland kernel

Akshay Pai, Stefan Sommer, Lauge Sørensen, Sune Darkner, Jon Sporring, Univ. of Copenhagen (Denmark); Mads Nielsen, Univ. of Copenhagen (Denmark) and Biomediq (Denmark)

Interpolating kernels are crucial to solving a stationary velocity field (SVF) based image registration problem. This is because, velocity fields need to be computed in non-integer locations during integration. The regularity in the solution to the SVF registration problem is controlled by the regularization term. In a variational formulation, this term is traditionally expressed as a squared norm which is a scalar inner product of the interpolating kernels parameterizing the velocity fields. The minimization of this term using the standard spline interpolation kernels (linear or cubic) is only approximative because of the lack of a compatible norm. In this paper, we propose to replace such interpolants with a norm-minimizing interpolant - the Wendland kernel which has the same computational simplicity like B-Splines. An application on the Alzheimer's disease neuroimaging initiative showed that Wendland SVF based measures separate (Alzheimer's disease v/s normal controls) better than both B-Spline SVFs ($p<0.05$ in amygdala) and B-Spline freeform deformation ($p<0.05$ in amygdala and cortical gray matter).

9413-114, Session PSWed

Tracking of Deformable Target in 2D Ultrasound Images

Lucas Royer, Institut de recherche technologique B-Com (France) and INRIA Rennes (France) and Institut National des Sciences Appliquées de Rennes (France); Maud Marchal, Institut National des Sciences Appliquées de Rennes (France) and Institut de recherche technologique B-Com (France); Anthony Le Bras, CHU Rennes (France); Guillaume Dardenne, Institut de recherche technologique B-Com (France); Alexandre Krupa, INRIA Rennes (France) and Institut de recherche technologique B-Com (France)

In several medical applications such as liver or kidney biopsies, an

anatomical region needs to be continuously tracked during the intervention. In this paper, we propose a novel approach for automatically tracking deformable target within 2D ultrasound images. Our approach uses only dense information combined with a physically-based model and has therefore the advantage of not using any fiducial marker nor a priori knowledge on the anatomical environment. The physical model is represented by a mass-spring damper system driven by different types of forces where the external forces are obtained by maximizing image similarity metric between a reference target and a deformed target across the time. This deformation is represented by a parametric warping model where the optimal parameters are estimated from the intensity variation. This warping function is well-suited to represent localized deformations in the ultrasound images because it directly links the forces applied on each mass with the motion of all the pixels in its vicinity. The internal forces constrain the deformation to physically plausible motions, and reduce the sensitivity to the speckle noise. The approach was validated on simulated and real data, both for rigid and free-form motions of soft tissues. The results are very promising since the deformable target could be tracked with a good accuracy for both types of motion. Our approach opens novel possibilities for computer-assisted interventions where deformable organs are involved and could be used as a new tool for interactive tracking of soft tissues in ultrasound images.

9413-115, Session PSWed

Accurate CT-MR image registration for deep brain stimulation: a multi-observer evaluation study

Jan Rühaak, Alexander Derksen, Stefan Heldmann, Marc Hallmann, Hans Meine, Fraunhofer MEVIS (Germany)

Since the first clinical interventions in the late 1980s, Deep Brain Stimulation (DBS) of the subthalamic nucleus has evolved into a very effective treatment option for patients with severe Parkinson's disease. DBS entails the implantation of an electrode that performs high frequency stimulations to a target area deep inside the brain. A very accurate placement of the electrode is a prerequisite for positive therapy outcome. The assessment of the intervention result is of central importance in DBS treatment and involves the registration of pre- and postinterventional scans.

In this paper, we present an image processing pipeline for highly accurate registration of postoperative CT to preoperative MR. Our method consists of a fully automatic pre-alignment using a detection of the skull tip in the CT which utilizes fuzzy connectedness and an intensity-based rigid registration. The registration uses the Normalized Gradient Fields distance measure in a multilevel Gauss-Newton optimization framework.

The accuracy of our method was extensively evaluated on 20 DBS datasets from clinical routine and compared with manual expert registrations. For each dataset, three independent registrations were available, thus allowing to relate algorithmic with expert performance. Our method achieved an average registration error of 0.95 mm in the target region around the subthalamic nucleus as compared to an inter-observer variability of 1.12 mm. Together with the short registration time of about five seconds on average, our method forms a very attractive package that can be considered ready for clinical use.

9413-116, Session PSWed

Annotation-free probabilistic atlas learning for robust anatomy detection in CT images

Astrid Franz, Nicole Schadewaldt, Heinrich Schulz, Torbjörn Vik, Philips Research (Germany); Lisa Kausch, Jan Modersitzki, Univ. zu Lübeck (Germany); Rafael Wiemker, Daniel Bystrov, Philips Research (Germany)

A fully automatic method generating a whole body atlas from CT images is presented. The atlas serves as a reference space for annotations. It is based on a large collection of partially overlapping medical images and a registration scheme. The atlas itself consists of probabilistic tissue type maps and can represent anatomical variations. The registration scheme is based on an entropy-like measure of these maps and is robust with respect to field-of-view variations. In contrast to other atlas generation methods, which typically rely on a sufficiently large set of annotations on training cases, the presented method requires only the images. An iterative refinement strategy is used to automatically stitch the images to build the atlas.

Affine registration of unseen CT images to the probabilistic atlas can be used to transfer reference annotations, e.g. organ models for segmentation initialization or reference bounding boxes for field-of-view selection. The robustness and generality of the method is shown using a three-fold cross-validation of the registration on a set of 316 CT images of unknown content and large anatomical variability. As an example, 17 organs are annotated in the atlas reference space and their localization in the test images is evaluated. The method yields a recall (sensitivity), specificity and precision of at least 96% and thus performs excellent in comparison to competitors.

9413-117, Session PSWed

On the usefulness of gradient information in multi-objective deformable image registration using a B-spline-based dual-dynamic transformation model: comparison of three optimization algorithms

Kleopatra Pirpinia, The Netherlands Cancer Institute (Netherlands); Peter A. N. Bosman, Ctr. voor Wiskunde en Informatica (Netherlands); Jan-Jakob Sonke, Marcel B. van Herk, The Netherlands Cancer Institute (Netherlands); Tanja Alderliesten, Academisch Medisch Centrum (Netherlands)

The use of gradient information is well-known to be highly useful in single-objective optimization-based image registration methods. However, its usefulness has not yet been investigated for deformable image registration from a multi-objective optimization perspective. To this end, within a previously introduced multi-objective optimization framework, we use a smooth B-spline-based dual-dynamic transformation model that allows us to derive gradient information analytically, while still being able to account for large deformations. Within the multi-objective framework, we previously employed a powerful evolutionary algorithm (EA) that computes and advances multiple outcomes at once, resulting in a set of solutions (a so-called Pareto front) that represent efficient trade-offs between the objectives. With the addition of the B-spline-based transformation model, we studied the usefulness of gradient information in multi-objective deformable image registration using three different optimization algorithms: the (gradientless) EA, a gradient-only algorithm, and a hybridization of these two. We evaluated the algorithms to register 2D MRI slices of the breast in prone and supine positions. Results demonstrate that gradient-based multi-objective optimization significantly speeds up optimization in the initial stages of optimization. However, allowing sufficient computational resources, better results could still be obtained with the EA. Ultimately, the hybrid EA found the best overall approximation of the optimal Pareto front, further indicating that adding gradient-based optimization for multi-objective optimization-based deformable image registration can indeed be beneficial.

9413-118, Session PSWed

Piecewise nonlinear image registration using DCT basis functions

Lin Gan, Gady Agam, Illinois Institute of Technology (United States)

A fundamental problem in medical image registration is the tradeoff between local constraints that are used to guarantee close matching to global constraints that are used to guarantee smoothness. To address this problem we propose a piecewise image registration approach using Discrete Cosine Transform (DCT) basis functions for a nonlinear model. The contributions of this paper are three-fold. First, we develop a multi-level piecewise registration framework that extends the concept of piecewise linear registration and works with any nonlinear deformation model. This framework is then applied to nonlinear DCT registration.

Second, we show how adaptive regularization could be applied to local piece registration, thus accounting for higher variability, and show how local mutual information based measurements can be used to dynamically determine the registration order of pieces. Third, we show how the proposed piecewise DCT can overcome the fundamental problem of a large curvature matrix inversion in global DCT when using high degrees of freedoms. The proposed approach can be viewed as an extension of global DCT registration where the overall model complexity is increased while achieving effective local regularization. Experimental evaluation results provide comparison of the proposed approach to piecewise linear registration using an affine transformation model and a global nonlinear registration using DCT model. Preliminary results show that the proposed approach achieves improved performance.

9413-119, Session PSWed

Personalized x-ray reconstruction of the proximal femur via a non-rigid 2D-3D registration

Weimin Yu, Philippe K. Zysset, Guoyan Zheng, Univ. Bern (Switzerland)

Purpose: To develop a method for a personalized reconstruction of a 3D model of the proximal femur from a limited number of 2D calibrated X-ray images.

Methods: A method for a non-rigid registration of a 3D volumetric template to a limited number of 2D C-arm images was developed. The 2D-3D non-rigid registration is done with a hierarchical two-stage strategy: the global scaled rigid registration stage followed by a regularized deformable b-spline registration stage. In both stages, a set of control points with uniform spacing are placed over the domain of the 3D volumetric template and the registrations are driven by computing updated positions of these control points, which then allows to accurately register the 3D volumetric template to the reference space of the C-arm images. Comprehensive experiments on simulated images, on images of cadaveric femurs and on clinical datasets are designed and conducted to evaluate the performance of the proposed approach.

Results: Evaluated on simulated X-ray images of 39 femurs, the present methods achieved an average mean surface distance of 1.15 mm and a mean Dice coefficient of 0.94, respectively. An average mean reconstruction accuracy of 1.4 mm was found when the present method was evaluated on calibrated C-arm images of 10 cadaveric femurs.

Conclusions: We developed and validated a new approach for the non-rigid registration of a 3D volumetric templete to 2D calibrated C-arm images and showed its application to the proximal femur. Studies conducted on simulated data and real data demonstrated the efficacy of the present approach.

9413-120, Session PSWed

A fast and memory efficient stationary wavelet transform for 3D cell segmentation

Dirk R. Padfield, GE Global Research (United States)

Wavelet approaches have proven effective in many segmentation applications and in particular in the segmentation of cells, which are blob-like in shape. We build upon an established wavelet segmentation algorithm

and demonstrate how to overcome some of its limitations based on the theoretical derivation of the compounding process of iterative convolutions. We demonstrate that the wavelet decomposition can be computed for any desired level directly without iterative decompositions that require additional computation and memory. This is especially important when dealing with large 3D volumes that consume significant amounts of memory and require intense computation. Our approach is generalized to automatically handle both 2D and 3D and also implicitly handles the anisotropic pixel size inherent in such datasets. Our results demonstrate a 28X improvement in speed and 8X improvement in memory efficiency for standard size 3D confocal image volumes without adversely affecting the accuracy.

9413-121, Session PSWed

Automated retinal fovea type distinction in spectral-domain optical coherence tomography of retinal vein occlusion

Jing Wu, Sebastian M. Waldstein, Bianca S. Gerendas, Georg Langs, Christian Simader, Ursula Schmidt-Erfurth, Medizinische Univ. Wien (Austria)

Spectral-domain Optical Coherence Tomography (SD-OCT) is a non-invasive modality for acquiring high-resolution, three-dimensional (3D) cross-sectional volumetric images of the retina and the subretinal layers. SD-OCT also allows the detailed imaging of retinal pathology, aiding clinicians in the diagnosis of sight degrading diseases such as age-related macular degeneration (AMD), glaucoma and retinal vein occlusion (RVO). Disease diagnosis, assessment, and treatment will require a patient to undergo multiple OCT scans, possibly using multiple scanners, to accurately and precisely gauge disease activity, progression and treatment success. However, cross-vendor imaging and patient movement may result in poor scan spatial correlation potentially leading to incorrect diagnosis or treatment analysis. The retinal fovea is the location of the highest visual acuity and is present in all patients, thus it is critical to vision and highly suitable for use as a primary landmark for cross-vendor/cross-patient registration for precise comparison of disease states. However, the location of the fovea in diseased eyes is extremely challenging to locate due to varying appearance and the presence of retinal layer destroying pathology. Thus categorising and detecting the fovea type is an important prior stage to automatically computing the fovea position.

Presented here is an automated cross-vendor method for fovea distinction in 3D SD-OCT scans of patients suffering from RVO, categorising scans into three distinct types. OCT scans are motion corrected and noise filtered followed by segmention using a kernel graph-cut approach. A statistically derived mask is applied to the resulting scan creating an ROI around the probable fovea position from which the top retinal surface is extracted. For a normal appearance retina, minimisation to zero thickness is computed using the top two retinal surfaces. 3D local minima detection and layer thickness analysis are used to differentiate between the remaining two fovea types. Fovea distinction validation employs ground truth fovea types identified by clinical experts at the Vienna Reading Center (VRC). The results presented here are intended to show the feasibility of this method for the accurate and reproducible distinction of retinal fovea types from multiple vendor 3D SD-OCT scans of patients suffering from RVO, for use in fovea position detection systems as a landmark for intra- and cross-vendor 3D OCT registration.

9413-122, Session PSWed

Evaluation of atlas-based white matter segmentation with eve

Andrew J. Plassard, Kendra E. Hinton, Vanderbilt Univ. (United States); Vijay Venkatraman, Christopher Gonzalez, Susan M. Resnick, National Institute on Aging (United

States); Bennett A. Landman, Vanderbilt Univ. (United States)

Multi-atlas labeling has come in wide spread use for whole brain labeling on magnetic resonance imaging. Recent challenges have shown that leading techniques are near (or at) human expert reproducibility for cortical gray matter labels. However, these approaches tend to treat white matter as essentially homogeneous (as white matter exhibits isointense signal on structural MRI). The state-of-the-art for white matter atlas is the single-subject Johns Hopkins Eve atlas. Numerous approaches have attempted to use tractography and/or orientation information to identify homologous white matter structures across subjects. Despite success with large tracts, these approaches have been plagued by difficulties in with subtle differences in course, low signal to noise, and complex structural relationships for smaller tracts. Here, we investigate use of atlas-based labeling to propagate the Eve atlas to unlabeled datasets. We evaluate single atlas labeling and multi-atlas labeling using synthetic atlases derived from the single manually labeled atlas. On 5 representative tracts for 10 subjects, we demonstrate that (1) single atlas labeling generally provides segmentations within 2mm mean surface distance, (2) morphologically constraining DTI labels within structural MRI white matter reduces variability, and (3) multi-atlas labeling did not improve accuracy. These efforts present a preliminary indication that single atlas labels with correction is reasonable, but caution should be applied. To purse multi-atlas labeling and more fully characterize overall performance, more labeled datasets would be necessary.

9413-123, Session PSWed

Bright-field cell image segmentation by principal component pursuit with an Ncut penalization

Yuehuan Chen, Justin W. Wan, Univ. of Waterloo (Canada)

Segmentation of cells in time-lapse bright-field microscopic images is crucial in understanding cell behaviors for oncological research. However, the complex nature of the cells makes it difficult to segment cells accurately. Furthermore, poor contrast, broken cell boundaries and the halo artifact pose additional challenges to this problem. Standard segmentation techniques such as edged-based methods, watershed, or active contours result in poor segmentation. Other existing methods for bright-field images cannot provide good results without localized segmentation steps. In this paper, we present two robust mathematical models to segment bright-field cells automatically for the entire image. These models treat cell image segmentation as a background subtraction problem, which can be formulated as a Principal Component Pursuit (PCP) problem. Our first segmentation model is formulated as a PCP with nonnegative constraints. In this approach, we exploit the sparse component of the PCP solution for identifying the cell pixels. However, there is no control on the quality of the sparse component and the nonzero entries can scatter all over the image, resulting in a noisy segmentation. The second model is an improvement of the first model by combining PCP with spectral clustering. Seemingly unrelated approaches, we combine the two techniques by incorporating normalized-cut in the PCP as a measure for the quality of the segmentation. These two models have been applied to a set of C2C12 cells obtained from bright-field microscopy. Experimental results demonstrate that the proposed models are effective in segmenting cells from bright-field images.

9413-124, Session PSWed

Locally-adaptive MR intensity models and MRF-based segmentation of multiple sclerosis lesions

Alfiia Galimzianova, Ziga Lesjak, Bo?tjan Likar, Franjo Pernu?, Ziga Spiclin, Univ. of Ljubljana (Slovenia)

Neuroimaging biomarkers are used to characterize several neurological diseases and require accurate and reliable segmentation of normal and pathological brain structures in MR images. For the segmentation of normal-appearing brain structures (NABT) in MR images of a healthy subject the use of locally-adaptive intensity models of NABT together with Markov random field (MRF) models was previously shown to give reliable and smooth NABT segmentation. However, these methods do not perform adequately on patient images, which besides the MR intensity bias and natural tissue-dependent intensity variability also contain an unpredictable amount of pathological structures. Because of the pathological structures and intensity variabilities, a robust estimation of the NABT intensity models is very difficult. In this paper, we propose a novel method for segmentation of pathological structures in brain MR images of multiple sclerosis (MS) patients that employs locally-adaptive NABT models and their robust estimation based on significance-level trimming of model likelihood. The NABT model outliers and MR hyperintensity signals define fuzzy membership map of the MS lesions, which is used in MRF energy minimization framework to obtain the MS lesion segmentation. The proposed method, using both local or global NABT model, and a state-of-the-art model outlier based MS lesion segmentation method were evaluated on 27 datasets of multi-sequence brain MR images of MS patients. The use of locally-adaptive versus global NABT intensity model significantly increased the accuracy of MS lesion segmentation, and also outperformed the state-of-the-art model outlier method in case of moderate and severe total lesion loads.

9413-125, Session PSWed

Improving the robustness of interventional 4D ultrasound segmentation through the use of personalized prior shape models

Daniel Barbosa, Life and Health Sciences Research Institute, Univ. of Minho (Portugal) and Instituto Politécnico do Cávado e do Ave (Portugal); Sandro Queirós, Life and Health Sciences Research Institute, Univ. of Minho (Portugal) and KU Leuven (Belgium); Pedro Morais, Life and Health Sciences Research Institute, Univ. of Minho (Portugal); Maria J. Baptista, Life and Health Sciences Research Institute, Univ. do Minho (Portugal); Mark Monaghan, Department of Cardiology, King's College Hospital (United Kingdom); Nuno F. Rodrigues, Instituto Politécnico do Cávado e do Ave (Portugal) and Life and Health Sciences Research Institute, Univ. do Minho (Portugal); Jan D'hooge, KU Leuven (Belgium); João L. Vilaça, Life and Health Sciences Research Institute, Univ. do Minho (Portugal) and Instituto Politécnico do Cávado e do Ave (Portugal)

Background: While fluoroscopy is still the most widely used imaging modality to guide cardiac interventions, the fusion of pre-operative MRI (Magnetic Resonance Imaging) with real-time intra-operative ultrasound (US) is rapidly gaining clinical acceptance as a viable alternative.

Materials and Methods: In order to improve the detection of the left ventricular surface in 4D ultrasound, we propose to take advantage of the pre-operative MRI scans to extract a realistic geometrical model representing both patient anatomy and relevant physiological targets. This high-level, personalized data could serve as prior information in the interventional setting, allowing increasing the accuracy of the anatomy extraction step in the US data. We have made use of a real-time 3D segmentation framework used in the recent past to solve the left ventricle (LV) segmentation problem in MR and US data independently and we take advantage of this common link to introduce the prior information as a soft penalty term in the ultrasound segmentation algorithm.

Results: We tested the proposed algorithm in a clinical dataset of 38 patients, which have undergone both MR and US scans. The introduction

of the personalized shape prior improves the accuracy and robustness of the LV segmentation, as supported by the error reduction on the estimated global LV morphological and functional indices when compared to core lab manual segmentation of the same US sequences.

Conclusion: The proposed method enables accurate and robust LV 4D segmentation, while its computational cost remains low. Thus, its application for online analysis of interventional data is possible and promising.

9413-126, Session PSWed

Novel multiresolution mammographic density segmentation using pseudo 3D features and adaptive cluster merging

Wenda He, Aberystwyth Univ. (United Kingdom); Arne Juette, Erica E. R. Denton, Norfolk and Norwich Univ. Hospital (United Kingdom); Reyer Zwiggelaar, Aberystwyth Univ. (United Kingdom)

Breast cancer is the most frequently diagnosed cancer in women. Early detection, precise identification of women at risk, and application of appropriate disease prevention measures are by far the most effective ways to overcome the disease. Successful mammographic density segmentation is a key aspect in deriving correct tissue composition, ensuring an accurate mammographic risk assessment. However, mammographic densities have not yet been fully incorporated in the non-image based risk prediction models, (e.g. the Gail and the Tyrer-Cuzick model), because of unreliable segmentation consistency and accuracy. This paper presents a novel multiresolution mammographic density segmentation, a concept of stack representation is proposed, and 3D texture features were extracted by adapting techniques based on classic 2D first-order statistics. An unsupervised clustering technique was employed to achieve mammographic segmentation, in which two improvements were made; 1) consistent segmentation by incorporating an optimal centroids initialisation step, and 2) significantly reduced the number of missegmentation by using an adaptive cluster merging technique. A set of full field digital mammograms was used in the evaluation. Visual assessment indicated substantial improvement on segmented anatomical structures and tissue specific areas, especially in low mammographic density categories. The developed method demonstrated an ability to improve the quality of mammographic segmentation via clustering, and results indicated an improvement of 26% in segmented image with good quality when compared with the standard clustering approach. This in turn can be found useful in early breast cancer detection, risk-stratified screening, and aiding radiologists in the process of decision making prior to surgery and/or treatment.

9413-127, Session PSWed

Segmentation of organs at risk in CT volumes of head, thorax, abdomen, and pelvis

Miaofei Han, Jinfeng Ma, Yan Li, Meiling Li, Yanli Song, Shanghai United Imaging Healthcare Co., Ltd. (China); Qiang Li, Shanghai Advanced Research Institute (China) and Shanghai United Imaging Healthcare Co., Ltd. (China)

Accurate segmentation of organs at risk (OARs) is a key step in treatment planning system (TPS) of image guided radiation therapy. We are developing three classes of methods to segment 17 organs at risk throughout the whole body, including brain, brain stem, eyes, mandible, temporomandibular joints, parotid glands, spinal cord, lungs, trachea, heart, livers, kidneys, spleen, prostate, rectum, femoral heads, and skin. The three classes of segmentation methods include (1) threshold-based methods for organs of large contrast with adjacent structures such as lungs, trachea, and skin; (2) context-driven Generalized Hough Transform-based methods combined with graph cut algorithm for robust localization and segmentation

of liver, kidneys and spleen; and (3) atlas and registration-based methods for segmentation of heart and all organs in CT volumes of head and pelvis. The segmentation accuracy for 9 representative organs was subjectively evaluated by two medical experts in three levels of score: 0, poor (unusable in clinical practice); 1, acceptable (minor revision needed); and 2, good (nearly no revision needed). A database was collected from Ruijin Hospital, Huashan Hospital, and Xuhui Central Hospital in Shanghai, China, including 127 head scans, 203 thoracic scans, 154 abdominal scans, and 73 pelvic scans. The percentages of "good" segmentation results were 97.6%, 81.1%, 87.4%, 86.7%, 91.1%, 94.1%, 82.5%, 79.9%, 86.4% for brain, eyes, mandible, heart, lungs, spinal cord, livers, spleen, and kidneys, respectively. Evaluation for other organs is in progress and will be provided when the full text is due.

9413-128, Session PSWed

Graph cut based co-segmentation of lung tumor in PET-CT Images

Wei Ju, Dehui Xiang, Bin Zhang, Xinjian Chen, Soochow Univ. (China)

Accurate segmentation of pulmonary tumor is important for clinicians to make appropriate diagnosis and treatment. Positron Emission Tomography (PET) and Computed Tomography (CT) are two commonly used imaging technologies for image-guided radiation therapy. In this study, we present a graph-based method to integrate the two modalities to segment the tumor simultaneously on PET and CT images. The co-segmentation problem is formulated as an energy minimization problem. Two weighted sub-graphs are constructed for PET and CT. The characteristic information of the two modalities is encoded on the edges of the graph. A context cost is enforced by adding context arcs to achieve consistent results between the two modalities. An optimal solution can be achieved by solving a maximum flow problem. The proposed segmentation method was validated on 18 sets of PET-CT images from different patients with non-small cell lung cancer (NSCLC). The quantitative results show significant improvement of our method with a mean DSC value 0.847.

9413-129, Session PSWed

Segmentation of the liver from abdominal MR images: a level-set approach

Anwar Abdalbari, Univ. of Ontario Institute of Technology (Canada); Xishi Huang, Univ. of Toronto (Canada); Jing Ren, Univ. of Ontario Institute of Technology (Canada)

The usage of prior knowledge in segmentation of abdominal MR images enables more accurate and comprehensive interpretation about the organ to segment. Prior knowledge about abdominal organ like liver vessels can be employed to get an accurate segmentation of the liver that leads to accurate diagnostics or treatment plan. In this paper, a new method for segmenting the liver from abdominal MR images using liver vessels as prior knowledge is proposed. The propose paper employs the technique of level set method to segment the liver from MR abdominal images. The speed image used in the level set method responsible for propagating and stopping the region growing at the boundaries. As a result of the poor contrast of the MR images between the liver and the surrounding organs i.e. stomach, kidneys, and heart causes leak of the segmented liver to those organs that lead to inaccurate or incorrect segmentation. For that reason, a second speed image is developed, as an extra term to the level set, to control the front propagation at weak edges with the help of the original speed image. The basic idea of the proposed approach is to use the second speed image as a boundary surface which is parallel to the area of the leak. The aim of the new speed image is to slow down the level set propagation and prevent the leak. The new speed image is a surface created by registering a pre-operative image using the bifurcation points of the prior knowledge vessels. The result of the proposed method shows superior outcome than other methods in the literature.

9413-130, Session PSWed

Semi-automatic 3D segmentation of costal cartilage in CT data from Pectus Excavatum patients

Daniel Barbosa, ICVS/3B's - PT Government Associate Lab. (Portugal) and DIGARC, Instituto Politécnico do Cávado e do Ave (Portugal) and School of Health Sciences, Univ. do Minho (Portugal); Sandro Queirós, ICVS/3B's - PT Government Associate Lab. (Portugal); Nuno F. Rodrigues, DIGARC, Instituto Politécnico do Cávado e do Ave (Portugal) and ICVS/3B's - PT Government Associate Lab. (Portugal); Jorge Correia-Pinto, João L. Vilaça, ICVS/3B's - PT Government Associate Lab. (Portugal)

Background: One of the current frontiers in the clinical management of Pectus Excavatum (PE) patients is the prediction of the surgical outcome prior to the intervention, through computerized simulation of the Nuss procedure. Prior work highlighted the difficulty of extracting an anatomically correct representation of the costal cartilage, which is crucial for accurate biomechanical simulation. In the present contribution, we aim to develop a framework for accurate and efficient 3D costal cartilage segmentation.

Materials and Methods: We take advantage of the costal cartilage tubular structure to detect it through multi-scale vesselness filtering. This information is then used in an interactive 2D initialization procedure which uses anatomical maximum intensity projections of 3D vesselness feature images to efficiently initialize the 3D segmentation process. We identify the cartilage tissue centerlines in these projected 2D images using a livewire approach. We finally refine the 3D cartilage surface through region-based sparse field level-sets.

Results: We have tested the proposed algorithm in 6 CT datasets from PE patients. A good segmentation performance was found against reference manual contouring, with an average Dice coefficient of 0.75±0.04 and an average mean surface distance of 1.69±0.30mm.

Conclusion: The proposed framework enables accurate 3D segmentation of costal cartilage in PE patients. Furthermore, the proposed method allows to interactively initialize the 3D segmentation problem in approximately 1 minute, which can positively contribute to an extended use of this tool in clinical practice, since current manual delineation of the costal cartilage can take up to an hour.

9413-131, Session PSWed

Automatic anatomy recognition of sparse objects

Liming Zhao, Chongqing Univ. (China); Jayaram K. Udupa, Dewey Odhner, Huiqian Wang, Yubing Tong, Drew A. Torigian, Univ. of Pennsylvania (United States)

A general body-wide automatic anatomy recognition (AAR) methodology was proposed in our previous work based on hierarchical fuzzy models of multitudes of objects which was not tied to any specific organ system, body region, or image modality. That work revealed the challenges encountered in modeling, recognizing, and delineating sparse objects throughout the body (compared to their non-sparse counterparts) if the models are based on the object's exact geometric representations. The challenges stem mainly from the variation in sparse objects in their shape, topology, geographic layout, and relationship to other objects. That led to the idea of modeling sparse objects not from the precise geometric representations of their samples but by using a properly designed optimal super form. This paper presents the underlying improved methodology which includes 5 steps: (a) Collecting image data from a specific population group G and body region ? and delineating in these images the objects in ? to be modeled; (b) Building a super form, S-form, for each object O in ?; (c) Refining the S-form of O to construct an optimal (minimal) super form, S*-form, which constitutes the (fuzzy) model of O; (d) Recognizing objects in ? using the S*-form; (e) Defining confounding and background objects in each S*-form for each object and performing optimal delineation. Our evaluations based on 100 3D CT image sets in the thorax and abdomen on 9 sparse objects indicate that substantially improved performance (FPVF~2%, FNVF~11%, and success where the previous approach failed) can be achieved using the new approach.

9413-132, Session PSWed

Phase congruency map driven brain tumour segmentation

Tünde Szilágyi, The Univ. of Debrecen (Hungary); Michael Brady, Univ. of Oxford (United Kingdom); Ervin Berényi, The Univ. of Debrecen (Hungary)

A level-set segmentation is developed for multi-modal brain Magnetic Resonance Images (MRI): T1w, T2w and Fluid Attenuated Inversion Recovery (FLAIR) in 2D. The novelty of the method is that physics based differential maps and monogenic (MS) local phase (LP) congruency (PC) drive the level-set and achieve better accuracy than earlier published algorithms.

The segmentation is performed in two steps. The data is re-sampled to isotropic voxel size, registered, and mean and variance normalized. T1w signal separate between brain and Cerebral Spinal Fluid (CSF). Smoothed T1w images form edge-maps used for the delineation of ventricles. T2w images characterise lesion textures, however, cannot differentiate lesions from CSF. FLAIR are in essence T2w with suppressed CSF, but have low resolution. The 2D Riesz and Log-Gabor filters are applied with 5 scales to derive the Riesz-weighted PC maps that enhance the structural information. The difference between the PC maps and the T2w MRI is driving the segmentation of the brain tumours. The results often have overspill into the ventricles. The final tumour maps are derived as the difference between the level-set function of the T1w and T2w-PC maps. The evaluation on the BRATS database achieves a mean DICE score 0.78 for real low grade (LG), 0.7 for high grade (HG), 0.78 for simulated LG and 0.86 for simulated HG tumours. Compared to earlier methods ours provides a higher accuracy for the LG tumours and lower accuracy for the HG. (Due to the fact that we do not use the contrast enhanced T1 MRI.)

9413-133, Session PSWed

Tumor segmentation on 18F-FDG PET: usefulness of locally connected conditional random fields

Mizuho Nishio, Atsushi K. Kono, Hisanobu Koyama, Tatsuya Nishii, Kazuro Sugimura, Kobe Univ. School of Medicine (Japan)

This study aimed to develop software for tumor segmentation on 18F-fluorodeoxyglucose (FDG) positron emission tomography (PET). To segment the tumor from the background, we used graph cut, whose segmentation energy was generally divided into two terms: the unary and pairwise terms. Locally connected conditional random fields (LCRF) was proposed for the pairwise term. In LCRF, a three-dimensional cubic window with length L was set for each voxel, and voxels within the window were considered for the pairwise term. To evaluate our method, 64 clinically suspected metastatic bone tumors were tested, which were revealed by FDG-PET. To obtain ground truth, the tumors were manually delineated via consensus of two board-certified radiologists. To compare the LCRF accuracy, other types of segmentation were also applied such as region-growing based on 35%, 40%, and 45% of the tumor maximum standardized uptake value (RG35, RG40, and RG45, respectively), SLIC superpixels (SS), and region-based active contour models (AC). To validate the tumor segmentation accuracy, a dice similarity coefficient (DSC) was calculated between manual segmentation and result of each technique. The DSC difference was tested using the Wilcoxon signed-rank test. The mean DSCs

of LCRF at L = 3, 5, 7, and 9 were 0.784, 0.801, 0.809, and 0.812, respectively. The mean DSCs of other techniques were RG35, 0.633; RG40, 0.675; RG45, 0.689; SS, 0.709; and AC, 0.758. The DSC differences between LCRF and other techniques were statistically significant (p <0.05). In conclusion, tumor segmentation was more reliably performed with LCRF relative to other techniques.

9413-134, Session PSWed

Automated segmentation of serous pigment epithelium detachment in SD-OCT images

Zhuli Sun, Xiang Dehui, Fei Shi, Xinjian Chen, Soochow Univ. (China); Haoyu Chen, Joint Shantou International Eye Center of Shantou Univ. and The Chinese Univ. of Hong Kong (China)

Pigment epithelium detachment (PED) is an important clinical manifestation of multiple chorio-retinal disease processes, which can cause the loss of central vision. A 3-D method is proposed to automatically segment serous PED in SD-OCT images. The proposed method consists of five steps: first, curvature anisotropic diffusion filter is applied to remove speckle noise. Second, graph search method is applied for abnormal retinal layers segmentation associated with retina pigment epithelium (RPE) deformation. During this process, Bruch's membrane, which doesn't show in the SD-OCT image, is estimated with convex hull algorithm. Third, the foreground seeds and background seeds are automatically obtained from retinal layers segmentation results. Fourth, the serous PED is segmented based on graph cut method. Finally, a post-processing step is applied to remove false positive regions based on mathematical morphology. The proposed method was tested on 20 SD-OCT volumes from 20 patients diagnosed with serous PED. The average true positive volume fraction (TPVF), false positive volume fraction (FPVF), dice similarity coefficient (DSC) and positive predictive value (PPV) are 97.19%, 0.03%, 96.34% and 95.59%, respectively. Linear regression analysis shows a strong correlation (r=0.975) comparing the segmented PED volumes with the ground truth labeled by an ophthalmology expert. The proposed method can provide clinicians with accurate quantitative information, including shape, size and position of the PED regions, which can assist diagnose and treatment.

9413-135, Session PSWed

Multi-atlas based segmentation of multiple organs in breast MRI

Xi Liang, Suman Sedai, IBM Research – Australia (Australia); Hongzhi Wang, IBM Research - Almaden (United States); Sisi Liang, Naveed Hashmi, IBM Research – Australia (Australia); Patrick Mcneillie, IBM Research - Almaden (United States); Sharbell Hashoul, IBM Research - Haifa (Israel)

Automatic segmentation of the breast, chest wall and heart is an important pre-processing step for automatic lesion detection of breast MR and dynamic contrast-enhanced MR studies. In this paper, we present a fully automatic segmentation procedure of multiple organs in breast MRI images using multi-atlas based methods. Our method starts by reducing the image inhomogeneity using anisotropic fusion method. We then build multiple atlases with labels of breast, chest wall and heart. These atlases are registered to a target image to obtain warped organ labels that are aligned to the target image. Given the warped organ labels, segmentation is performed via label fusion. In this paper, we evaluate various label fusion methods and compare their performance on segmenting multiple anatomical structures in breast MRI.

Our evaluation is conducted through a leave-one-out experiment on 13 breast MR images. The DICE similarity coefficient between automatic

segmentation and manual segmentation is employed to quantify the segmentation quality. In summary, MV and patch-based methods showed the worst results in segmenting all objects of breast, chest wall and heart. STAPLE method achieved a better DICE value in breast and heart, compared to MV and patch-based methods. Joint label fusion was shown to be able to further improve the result over all regions. The most recent local random forest label fusion method using radius 3 and 5 pixels achieved similar results and both of them are higher than the remaining methods. The t-test showed that the segmentation results using the two radius were not significantly different.

9413-136, Session PSWed

Locating seed points for multi-organ automatic segmentation using non-rigid registration and organ annotations

Ranveer R. Joyseeree, Haute Ecole Spécialisée de Suisse occidentale (Switzerland) and ETH Zürich (Switzerland); Henning Mueller, Haute Ecole Spécialisée de Suisse occidentale (Switzerland)

Organ segmentation is helpful for decision--support in diagnostic medicine.

Region--growing segmentation algorithms are popular but usually require that clinicians place seed points manually. A method to automatically calculate the seed points for segmenting organs in three--dimensional (3D), non--annotated Computed Tomography (CT) and Magnetic Resonance (MR) volumes from the VISCERAL dataset is presented in this paper. It precludes the need for manual input, thereby saving time. It also has the advantage of potentially being a simple yet effective means of finding reliable seed points for segmentation.

B--spline registration is used to align expert annotations (from the VISCERAL dataset) of each organ of interest in order to build a probability map for their respective location in a chosen reference frame.

The centroid of each is determined.

B--spline registration is then used to warp the calculated centroids onto the volumes to be segmented. Existing segmentation algorithms may then be applied with the mapped centroids as seed points and the warped probability maps as an aid to the stopping criteria for segmentation.

The above method was tested on contrast--enhanced, thorax--abdomen CT images using a simple region--growing segmentation algorithm and promising results were obtained and are presented in this paper. The causes of observed segmentation problems were identified and countermeasures were proposed in order to achieve even better results in the next stage of development which will involve a wider variety of MR and CT images.

9413-137, Session PSWed

Optimization-based interactive segmentation interface for multi-region problems

John S. H. Baxter, Martin Rajchl, Elvis C. S. Chen, Terry M. Peters, Robarts Research Institute (Canada)

Interactive segmentation is becoming of increasing interest to the medical imaging community in that it combines the positive aspects of both manual and automated segmentation. However, general purpose tools have been lacking in terms of segmenting multiple regions simultaneously with a high degree of coupling between groups of labels. Hierarchical max-flow segmentation has taken advantage of this coupling for individual applications, but until recently these algorithms were constrained to a particular hierarchy and could not be considered general-purpose. With generalized hierarchical max-flow segmentation, the hierarchy for any given segmentation problem is specified in run-time, allowing different hierarchies to be quickly explored. This paper presents a novel interactive

segmentation interface, which uses generalized hierarchical max-flow for optimization-based multi-region segmentation guided by user-defined seeds. Applications in cardiac segmentation are given.

9413-138, Session PSWed

Live minimal path for interactive segmentation of medical images

Gabriel Chartrand, Ecole de Technologie Supérieure (Canada); An Tang, Lab. de recherche en Imagerie et Orthopédie (Canada) and Ctr. de recherche du CHUM (Canada); Ramnada Chav, Thierry Cresson, Steeve Chantrel, Jacques A. de Guise, Ecole de Technologie Supérieure (Canada)

Medical image segmentation is nowadays required in a growing number of research projects and medical device development. Since dedicated automatic segmentation methods are not always available, generic and efficient interactive tools can greatly alleviate the manual segmentation task. In this paper we propose an interactive segmentation tool based on image warping and minimal path segmentation that is efficient for a wide variety of segmentation tasks. While the user roughly delineates the desired structure's boundary, a narrow band along the cursor's path is straightened, providing an ideal subspace for feature aligned filtering and minimal path algorithm. Once the segmentation is performed on the narrow band, the path is warped back onto the original image, precisely delineating the desired structure. This tool was found to have a highly intuitive dynamic behavior. It is especially efficient against misleading edges and required only coarse interaction from the user to achieve good precision. The proposed segmentation method was tested for 10 difficult liver segmentation tasks on CT and MRI images, and the resulting 2D overlap Dice coefficient was 0.990 on average.

9413-139, Session PSWed

Combined use of high-density and volumetric optical coherence tomography for the segmentation of neural canal opening in cases of optic nerve edema

Jui-Kai Wang, The Univ. of Iowa (United States); Randy H. Kardon, The Univ. of Iowa Hospitals and Clinics (United States) and Iowa City VA Medical Ctr. (United States); Mona K. Garvin, Iowa City VA Medical Ctr. (United States) and The Univ. of Iowa (United States)

In cases of optic nerve edema, the presence of the swelling reduces the visibility of the underlying neural canal opening (NCO) within spectral-domain optical coherence tomography (SD-OCT) volumes. Correspondingly, traditional SD-OCT-based NCO segmentation methods often overestimate the size of the NCO. The visibility of the NCO can be improved using high-density 2D raster scans, but such scans do not provide 3D contextual image information. In this work, we present a semi-automated approach for the segmentation of the NCO in cases of optic nerve edema by combining image information from volumetric and high-density raster SD-OCT image sequences. In particular, for each subject, the high-density OCT scans (which contains five individual B-scans) and the volumetric OCT images are first separately segmented, and then the five high-density B-scans are automatically registered to the volumetric OCT image. Next, six NCO points are placed (manually, in this work) in the central three high-density OCT B-scans (two points for each B-scan) and further are automatically transferred into the OCT volume. Utilizing a combination of these mapped points and the 3D image information from the volumetric scans, a graph-based approach is used to identify the complete NCO on the OCT en-face image. The segmented NCO points using the new approach were significantly closer to expert-marked points than the segmented NCO points

using a traditional approach (root mean square differences in pixels: 26.55 vs. 1.99, p < 0.001).

9413-140, Session PSWed

Intelligent editing for post-processing of ROI segmentation

Kongkuo Lu, Philips Research North America (United States)

Segmentation of suspect lesions, or regions of interest, is a preliminary but vital step for computer-aided breast cancer diagnosis, but the task is quite challenging due to image quality and the complicated phenomena that are usually involved with the lesions. On one hand, it is possible for physicians and clinicians to dig out more information from imaging; on another hand, efficient, robust, and accurate segmentation of such kind of anatomical lesions is often a difficult and open task to researcher and technical development. As a counterbalance between automatic methods, which are usually highly application dependent, and manual approaches, which are too time consuming, live wire, which provide full user control during segmentation while minimizing user interaction, is a promising option for assisting in breast lesion segmentation in ultrasound (US) images. This work proposes a live-wire-based adjustment method to further extend its potentials in computer-aided diagnosis (CAD) applications. It allows for local boundary adjustment, based on the live-wire paradigms, for a given segmentation, and can be attached as a post-process step to the live wire method or other segmentation approaches.

9413-141, Session PSWed

Fast and memory-efficient LOGISMOS graph search for intraretinal layer segmentation of 3D macular OCT scans

Kyungmoo Lee, Li Zhang, Iowa Institute for Biomedical Imaging (United States) and The Univ. of Iowa (United States); Michael D. Abràmoff, Iowa Institute for Biomedical Imaging (United States) and The Univ. of Iowa (United States) and Iowa City VA Medical Ctr (United States); Milan Sonka, Iowa Institute for Biomedical Imaging (United States) and The Univ. of Iowa (United States)

Image segmentation is important for quantitative analysis of medical image data. Recently, our research group has introduced a 3-D graph search method which can simultaneously segment optimal interacting surfaces with respect to the cost function in volumetric images. Although it provides excellent segmentation accuracy, it is computationally demanding (both CPU and memory) to simultaneously segment multiple surfaces from large volumetric images. Therefore, we propose a new, fast, and memory-efficient graph search method for intraretinal layer segmentation of 3-D macular optical coherence tomograpy (OCT) scans. The key idea is to reduce the size of a graph by combining the nodes with high costs based on the multiscale approach. The new approach requires significantly less memory and achieves significantly faster processing speeds (p < 0.01) with only small segmentation differences compared to the original graph search method. This paper discusses sub-optimality of this approach and assesses trade-off relationships between decreasing processing speed and increasing segmentation differences from that of the original method as a function of employed scale of the underlying graph construction.

9413-142, Session PSWed

Segmentation of bone structures in 3D CT images based on continuous max-flow optimization

Jose-Antonio Pérez-Carrasco, Instituto de Microelectrónica de Sevilla (Spain); Begoña Acha-Piñero, Maria del Carmen Serrano Gotarredona, Univ. de Sevilla (Spain)

In this paper an algorithm to carry out the automatic segmentation of bone structures in 3D CT images has been implemented. Automatic segmentation of bone structures is of special interest for radiologists and surgeons to analyze bone diseases or to plan some surgical interventions. The segmentation of bone structures is a complicated task as bones usually present intensities overlapping with those of surrounding tissues (muscles, organs, etc). This overlapping is mainly due to the composition of bones and to the presence of some diseases such as Osteoarthritis, Osteoporosis, etc. Moreover, segmentation of bone structures is a very time-consuming task due to the 3D essence of the bones. Usually, this segmentation is implemented manually or with algorithms using simple techniques such as thresholding and thus providing bad results. In this paper gray information and 3D statistical information have been combined to be used as input to a continuous max-flow algorithm. Twenty CT images have been tested and different coefficients such as DICE, Jaccard, Sensitivity and Positive Predictive Value (PPV) indexes have been computed to assess the performance of our implementation. Dice and Sensitivity values above 0.91 and 0.97 respectively were obtained. A comparison with Level Sets and thresholding techniques has been carried out and our results outperformed them in terms of accuracy.

9413-143, Session PSWed

Segmentation of branching vascular structures using adaptive subdivision surface fitting

Pieter H. Kitslaar, Leiden Univ. Medical Ctr. (Netherlands) and Medis medical imaging systems bv (Netherlands); Ronald van't Klooster, Marius Staring, Boudewijn P. F. Lelieveldt, Rob J. van der Geest, Leiden Univ. Medical Ctr. (Netherlands)

This paper describes a novel method for segmentation and modeling of branching vessel structures in medical images using adaptive subdivision surfaces fitting. The method starts with a rough initial skeleton model of the vessel structure. A coarse control mesh of hexagonal ring elements and bifurcation templates is constructed from this skeleton. Then, a smooth tubular surface is obtained from this coarse mesh using a standard subdivision scheme. This subdivision surface is iteratively fitted to the image. During the fitting, the target update locations of the subdivision surface are obtained using a scanline search along the surface normals, finding the maximum gradient magnitude (of the imaging data). In addition to this surface fitting framework, we propose an adaptive mesh refinement scheme. In this step the coarse control mesh is updated based on the current segmentation result, enabling adaptation to varying vessel lumen diameters. This enhances the robustness and flexibility of the method and reduces the amount of prior knowledge needed to create the initial skeletal model. The method was applied to public patient data from the Carotid Bifurcation Algorithm Evaluation Framework resulting in an average dice index of 89.2% with the ground truth. Application of the method to the complex vascular structure of a coronary tree and to MRI images were performed to show the versatility and flexibility of the proposed framework.

9413-144, Session PSWed

A fully automatic multi-atlas based segmentation method for prostate MR images

Zhiqiang Tian, Lizhi Liu, Baowei Fei, Emory Univ. (United States)

Most of multi-atlas segmentation methods focus on the registration between the full-size volumes. Although, the transformations obtained from these registrations may be accurate for the global field of view of images, they may not accurate for the local prostate region. This is because that different magnetic resonance (MR) images have different fields of view and large anatomical variability around the prostate. To overcome this limitation, we proposed a two-stage prostate segmentation method based on a fully automatic multi-atlas framework, which includes the detection stage (locating the prostate) and the segmentation stage (extracting the prostate). The purpose of the first stage is to find a cuboid that contains the whole prostate as small cubage as possible. In this paper, the cuboid including the prostate is detected by registering atlas edge volumes to the target volume while an edge detection algorithm is applied to every slice in the volumes. At the second stage, the proposed method focuses on the registration in the region of the prostate vicinity, which can improve the accuracy of the prostate segmentation significantly. We evaluated the proposed method on 12 patient MR volumes by performing a leave-one-out study. Dice similarity coefficient (DSC) and Hausdorff distance (HD) are used to quantify the difference between our method and the manual ground truth. The proposed method yielded a DSC of 83.4%±4.3%, and a HD of 9.3 mm±2.6 mm. The fully automated segmentation method can provide a useful tool in many prostate imaging applications.

9413-145, Session PSWed

Relaxation time based classification of magnetic resonance brain images

Fabio Baselice, Giampaolo Ferraioli, Vito Pascazio, Univ. degli Studi di Napoli Parthenope (Italy)

Focusing on brain MR images, segmentation is a very useful tool in the study of some disorders, such as multiple sclerosis, or in quantification of white matter lesions.

Historically, first approaches were based on manual delineation by a human expert. Such approach had several disadvantages, in particular a considerable inter- and intra-rater variability.

The currently adopted techniques can be divided into two categories: structural and statistical. Among them, the most adopted are classification-based segmentation, region-based segmentation and contour-based segmentation. Within this manuscript, we focus on classification-based approaches, i.e. jointly segment and classify tissues across the imaged slice: voxels are classified and labeled as belonging to a particular tissue class according to a certain criterion. The simplest method is based on thresholding. While the application of a threshold is a trivial operation, the determination of its ideal value has to be carefully done. Basic approaches consider the Gaussian Mixture model of tissues signal intensities, i.e. a one dimensional problem. If a proper post processing is not implemented, such approach produces poor results in case of low SNR and tissues with similar signal intensities.

We propose a joint segmentation and classification in a 2D space able to operate after the estimation of tissue relaxation times. The ideal thresholds, which in this case are 2D curves, are automatically determined starting from the statistical distribution of the T1 and T2 estimators, providing the optimal decision regions.

9413-146, Session PSWed

Identifying the optimal segmentors for mass classification in mammograms

Yu Zhang, East-West Univ. (United States); Noriko Tomuro, Jacob D. Furst, Daniela S. Raicu, DePaul Univ. (United States)

In previous research, we build multiple segmentations for each ROI image to adapt the varied intensity contrast ranges of mammograms. Each of such segmentations is called a "weak segmentor", since there is no one segmentation which produces the optimal results for all images. In previous study, we used the successful segmentation rates to evaluate the performance of each segmentor. However, by using this evaluation method, the quality of the segmentation is not fully revealed.

In this research, we propose using regression weights of the extracted shape features to evaluate the segmentation results and identify the optimal segmentors for mass classification.

In our experiment, we built six weak segmentors (three edge-based and three region-based segmentors). From mass contours detected by the segmentation, shape features are extracted. There are a total of 90 shape features were computed from 6 weak segmentors x 15 shape descriptors for feature extraction. We feed the extracted shape features to a logistic regression model to obtain a set of feature regression weights, where a feature with a larger regression weight (absolute value) indicates the feature has more influence.

Among six weak segmentors, we identify three optimal segmentors with higher regression weights. The optimal segmentors have more contributions for mass classification than other segmentors.

9413-147, Session PSWed

Interactive image segmentation framework based on control theory

Liangjia Zhu, Ivan Kolesov, Stony Brook Univ. (United States); Vadim Ratner, Stony Brook University (United States); Peter Karasev, Agilent Technologies, Inc. (United States); Allen R. Tannenbaum, Stony Brook Univ. (United States)

Segmentation of anatomical structures in medical imagery is a key step in a variety of clinical applications.

Designing a generic, automated method that works for various structures and imaging modalities is a daunting task. Instead of proposing a new specific segmentation algorithm, in this paper, we present a general design principle on how to integrate user interactions from the perspective of control theory. In this formulation, Lyapunov stability analysis is employed to design and analyze an interactive segmentation system. The effectiveness and robustness of the proposed method are demonstrated.

9413-148, Session PSWed

Shape index distribution based local surface complexity applied to the human cortex

Sun Hyung Kim, The Univ. of North Carolina at Chapel Hill (United States); Vladimir S. Fonov, D. Louis Collins, McConnell Brain Imaging Ctr. (Canada) and Montreal Neurological Hospital and Institute (Canada); Guido Gerig, Scientific Computing and Imaging Institute (United States) and The Univ. of Utah (United States); Martin A. Styner, The Univ. of North Carolina at Chapel Hill (United States)

and on behalf of the IBIS Network (United States)

The quantification of local surface complexity in the human cortex has shown to be of interest in investigating population differences as well as developmental changes in neurodegenerative or neurodevelopment diseases. We propose a novel assessment method that represents local complexity as the difference between the observed distribution of local surface topology to its best fit basic topology model. This difference is estimated via Earth Move Distance (EMD) and the local surface topology is quantified via the Shape Index (SI) measure. The EMD scores ranges from simple complexity (0.0), which indicates a consistent local surface topology, up to high complexity (0.5), which indicates a highly variable local surface topology. The basic topology models are categorized as 9 geometric situation modeling situations such as crowns, ridges and fundi of cortical gyro and sulci. We apply a geodesic kernel to calculate the local SI distribution within a given region. In our experiments, we obtained the results of local complexity that shows generally higher complexity in the gyral/sulcal wall regions and lower complexity in some gyral ridges and lowest complexity in sulcal fundus areas. In addition, we show preliminary results of increased complexity across most of the cortical surface, hypothesized to be due to the changes such as development of sulcal pits.

9413-149, Session PSWed

Cochlear shape description and analyzing via medial models

Johannes Gaa, Lüder A. Kahrs, Samuel Müller, Leibniz Univ. Hannover (Germany); Omid Majdani, Medizinische Hochschule Hannover (Germany); Tobias Ortmaier, Leibniz Univ. Hannover (Germany)

Planning and analyzing of surgical interventions are often based on computer models derived by patient specific computed tomography images. In the field of cochlear implant insertion the modeling of several structures of inner ear image data is needed. One structure is the overall helical shape of the cochlea itself. We analyze the cochlea by applying statistical shape models with medial representation and the cochlea is considered as tubular structure. A compact model representing the skeleton of training data and an atomic composition of the structure is built. We reduce the representation to a linear chain of atoms. As result a compact discrete model is possible. It is demonstrated how to place the atoms hub and build up their correspondence through a population of training data. The outcome of the applied representation is discussed in terms of impact on automated segmentation algorithms and known advantages of medial models are revisited.

Conference 9414: Computer-Aided Diagnosis

Sunday - Wednesday 22–25 February 2015

Part of Proceedings of SPIE Vol. 9414 Medical Imaging 2015: Computer-Aided Diagnosis

9414-1, Session 1

Automatic diagnosis of inflammatory muscle disease for MRI using computer-extracted features of bivariate histograms

James V. Jack, Loughborough Univ. (United Kingdom); Terence A. Jones, Charles E. Hutchinson, The Univ. of Warwick (United Kingdom); Helmut E. Bez, Eran A. Edirisinghe, Loughborough Univ. (United Kingdom)

Inflammatory muscle disease is a group of rare idiopathic conditions that cause progressive skeletal muscle weakness. Diagnosis typically requires an assortment of clinical tests, including magnetic resonance imaging (MRI) of the thigh muscles to assess fat infiltration and inflammation. We hypothesise that features from multi-spectral MRI can accurately predict patient diagnosis, without the need for additional tests. A novel method is presented using computer-extracted features of the T1-STIR bivariate histogram to detect disease. The dataset comprised of 78 image-pairs from patients with inflammatory muscle disease and 61 image-pairs from control cases with no disease. T1 and STIR slices were co-registered and the background discarded. A feature vector was designed to measure the distribution of normalised intensity values (e.g. standard deviation, kurtosis, gini) for the muscle, fat, and leg regions of the bivariate histogram. Feature dimensionality was reduced using an evaluator algorithm to select the most independent features and these were used to train a Bayes network to predicted patient diagnosis on a per-slice basis. 10-fold cross-validation was employed in both phases to ensure robustness. The system attained 87% sensitivity and 83% specificity (ROC area 0.93). These results support the hypothesis that accurate diagnosis of inflammatory muscle disease is possible using MRI alone, without the need for additional clinical tests, with the potential benefit of faster diagnosis and better care for patients with this group of rare conditions.

9414-2, Session 1

Segmentation of the sternum from low-dose chest CT images

Shuang Liu, Yiting Xie, Anthony P. Reeves, Cornell Univ. (United States)

Segmentation of the sternum in medical images is of clinical significance as it frequently serves as a stable reference to image registration and segmentation of other organs in the chest region. In this paper we present a fully automated algorithm to segment the sternum in low-dose chest CT images (LDCT). The proposed algorithm first locates an axial seed slice and then segments the sternum cross section on the seed slice by matching a rectangle model. Furthermore, it tracks and segments the complete sternum in the cranial and caudal direction respectively through sequential axial slices starting from the seed slice. The cross section on each axial slice is segmented using score functions that are designed to have local maxima at the boundaries of the sternum. Finally, the sternal angle is localized. The algorithm is designed to be specifically robust with respect to cartilage calcification and to accommodate the high-noise levels encountered with LDCT images. Segmentation of 351 cases from public datasets was evaluated visually with only 1 failing to produce a usable segmentation. 87.2% of the 351 images have GOOD segmentation and 12.5% have ACCEPTABLE segmentation. The sternal body segmentation and the localization of the sternal angle and the vertical extents of the sternum were also evaluated quantitatively for 25 randomly selected GOOD cases and 25 ACCEPTABLE cases. The overall weighted mean DC of 0.897 and weighted mean distance error of 2.88 mm demonstrates that the algorithm achieves good performance in segmenting the sternal body and localizing the sternal angle.

9414-3, Session 1

Detection of degenerative change in lateral projection cervical spine x-ray images

Beyrem Jebri, Ecole Nationale Superieure D'Informatique Pour L'Industrie et L'Entreprise (France); Michael Phillips, City Univ. London (United Kingdom); Karen Knapp, Univ. of Exeter (United Kingdom); Andy Appelboam, Royal Devon and Exeter Hospital, NHS (United Kingdom); Adam Reuben, Royal Devon and Exeter Hospital, RHS (United Kingdom); Greg Slabaugh, City Univ. London (United Kingdom)

Degenerative change to the cervical spine can be accompanied by neck pain, which can result from narrowing of the intervertebral disc space, osteophytes, and spondylosis. In a lateral x-ray image of the cervical spine, degenerative changes are characterized by vertebral bodies that have indistinct boundaries and limited spacing between vertebrae. In this paper, we present a machine learning approach to detect degenerative change in lateral x-ray images of the cervical spine. Starting from a user-supplied set of points in the center of each vertebral body, we fit a central spline, from which a region of interest is extracted and image features are computed. A Random Forest classifier labels regions as degenerative change or normal. Leave-one-out cross-validation studies performed on a dataset of 103 patients demonstrates performance of above 95% accuracy.

DISCUSSION AND CONCLUSION: Some degenerative changes cannot be diagnosed solely from the vertebral body region; for example DCs in the spinous processes would be missed by our method; this is an area of future work. Nonetheless, the proposed method provides an accuracy of above 95% for the vertebral body region, which is a very encouraging result.

REFERENCES

[1] J. S. Roh, A. L. Teng, J. U. Yoo, J. Davis, C. Furey, and H. H. Bohlman, "Degenerative disorders of the lumbar and cervical spine," Orhopedic Clinics of North America 36(3), 2005.

[2] M. Benjelloun, S. Mahmoudi, and F. Lecron, "A framework of vertebra segmentation using the active shape model-based approach," International Journal of Biomedical Imaging , 2011.

[3] T. Vrtovec, F. Pernus, and B. Likar, "A review of methods for quantitative evaluation of spinal curvature," European Spine Journal 18(5), 2009.

[4] A. Bosch, A. Zisserman, and X. Munoz, "Image classification using random forests and ferns," in Intl. Conf. on Computer Vision, 2007.

[5] F. Lecron, M. Benjelloun, and S. Mahmoudi, "Fully Automatic Vertebra Detection in X-Ray Images Based on Multi-Class SVM," in SPIE Medical Imaging: Image Processing, 2012.

9414-4, Session 1

Diagnostic index of 3D osteoarthritic changes in TMJ condylar morphology

Liliane R. Gomes, Univ. of Michigan (United States) and Univ. Estadual Paulista (Brazil); Marcelo Gomes, Bryan Jung, Univ. of Michigan (United States); Beatriz Paniagua, The Univ. of North Carolina at Chapel Hill (United States); Antonio C. Ruellas, Univ. of Michigan (United States); João Roberto Gonçalves, Univ. Estadual Paulista (Brazil); Martin A. Styner, The Univ. of North Carolina at Chapel Hill (United States); Larry M. Wolford, Baylor University Medical Center (United States); Lucia Cevidanes, Univ. of

Michigan (United States)

The objective of this study was to investigate 3D morphological variations in 169 Temporomandibular Joint (TMJ) condyles, using novel imaging statistical approaches. Cone beam Computed Tomography (CBCT) scans were acquired from 69 patients with long-term TMJ Osteoarthritis (OA) (39.1 ± 15.7 years), 15 patients at initial diagnosis of OA (44.9 ± 14.8 years) and 7 healthy controls (43 ± 12.4 years). 3D surface models of the condyles were constructed, and Shape Correspondence was used to establish correspondent points on each model. The statistical framework included a multivariate analysis of covariance, and Direction-Projection-Permutation (DiProPerm) for testing statistical significance of the differences between healthy control and the OA group determined by clinical and radiographic diagnoses. Unsupervised classification using hierarchical agglomerative clustering (HAC) was also conducted. Condylar morphology in OA and healthy subjects varied widely. 1000 permutation statistics of DiProPerm supported a significant difference between the healthy control group and the initial diagnosis of OA group (t=6.6, empirical p-value=0.006), and between healthy and long-term diagnosis of OA group (t=7.2, empirical p-value=0). Compared with healthy controls, OA average condyle was significantly smaller in all dimensions except its anterior surface. Bone resorption at the articular surface, particularly at the lateral pole was statistically significant at initial diagnosis of OA, and the anterior surface of the condyle presented reparative bone apposition that was more marked at long-term diagnosis. Meaningful unsupervised classification results were also observed. This new statistical modeling of condylar morphology allows the development of more targeted statistical classifications of this condition than previously possible.

9414-5, Session 1

3D statistical shape models incorporating 3D random forest regression voting for robust CT liver segmentation

Tobias Norajitra, Hans-Peter Meinzer, Klaus H. Maier-Hein, Deutsches Krebsforschungszentrum (Germany)

During image segmentation, 3D Statistical Shape Models (SSM) usually conduct a limited search for meaningful target points within one-dimensional search profiles perpendicular to the model surface. In addition, the description of surface landmark appearance is limited to local profiles while weak learners are employed for landmark detection, altogether leading to landmark ambiguities and limited target search coverage. As a result, the segmentation is sensitive to the preceding model initialization. We present a new method for 3D SSM segmentation based on 3D Random Forest Regression Voting. For each surface landmark, a Random Forest is trained that learns a 3D spatial displacement function between the according reference landmark and a set of surrounding sample points, based on an inifinite set of randomized 3D Haar-like features. Candidate search is then conducted within 3D search spaces, where each trained tree makes voxelwise predictions on the target landmark position, contributing to a common voting map that reflects the overall position estimate. We have conducted segmentation experiments on a set of 45 CT volumes of the human liver, where 40 images were randomly chosen for training and 5 for testing. Without any optimizations, using a simple candidate selection and one single high-resolution approach, our algorithm achieved excellent results, underlining the potential of our approach in terms of search coverage and capture range.

9414-6, Session 2

Pulmonary embolism detection using localized vessel-based features in dual energy CT

Yashin Dicente Cid, HES-SO Valais (Switzerland) and Univ. of Geneva (Switzerland); Adrien Depeursinge, Antonio

Foncubierta Rodríguez, HES-SO Valais (Switzerland); Alexandra Platon, Pierre-Alexandre Poletti, Hôpitaux Univ. de Genève (Switzerland); Henning Müller, HES-SO Valais (Switzerland) and Univ. of Geneva (Switzerland)

Pulmonary embolism (PE) affects up to 600,000 patients and contributes to at least 100,000 deaths every year in the United States alone. Diagnosis of PE can be difficult as most symptoms are unspecific. Early diagnosis is essential for successful treatment, and various image–based procedures have been proposed for improving computer–aided diagnosis of PE. In this paper a novel method for detecting PE is proposed based on localized vessel–based features computed in Dual Energy CT (DECT) images. DECT provides 4D data sampled at the three spatial coordinates and the energy level used for acquisition. The proposed features encode the variation of the Hounsfield Units among the different levels and the amount of iodine contrast in each vessel. Results show that very simple features are able to classify pulmonary embolism patients with approximately 75% accuracy on a lobe basis. Prior segmentation of the lung lobes is not necessary and atlas–based classification obtains similar accuracy levels (73%).

9414-7, Session 2

Robustness evaluation of a computer-aided detection system for pulmonary embolism (PE) in CTPA using independent test sets from multiple institutions

Chuan Zhou, Heang-Ping Chan, Aamer R. Chughtai, Jean W. Kuriakose, Ella A. Kazerooni, Lubomir M. Hadjiiski, Jun Wei, Smita Patel, Univ. of Michigan Health System (United States)

We have developed a computer-aided diagnosis (CAD) system for assisting radiologists in detection of pulmonary embolism (PE) in computed tomographic pulmonary angiographic (CTPA) images. The CAD system includes stages of pulmonary vessel segmentation, prescreening of PE candidates and false positive (FP) reduction to identify suspicious PEs. The system was trained in a previous study with 59 CTPA PE cases collected retrospectively from our patient files (UM set) with IRB approval. The purpose of this study is to evaluate the performance of our CAD system using two independent test sets of CTPA cases. One set contained 49 new PE cases retrospectively collected from UM and the other, 69 PE cases from the PIOPED II data set collected by multiple institutions with access permission. 185 and 800 PEs were manually marked by experienced thoracic radiologists as reference standard for the UM and the PIOPED test sets, respectively. The FP classifier obtained test Az values of 0.842 and 0.843 for the UM and PIOPED test sets, respectively. FROC analysis indicated that the CAD system achieved an overall sensitivity of 80% at 11.2 FPs/case for the UM test set and 8.7 FPs/case for the PIOPED test set.

9414-8, Session 2

Automatic detection of spiculation of pulmonary nodules in computed tomography images

Francesco Ciompi, Radboud Univ. Nijmegen (Netherlands); Colin Jacobs, Radboud Univ. Nijmegen Medical Ctr. (Netherlands); Ernst T. H. Scholten, Sarah van Riel, Diagnostic Image Analysis Group (Netherlands); Mathilde M. Winkler Wille, Gentofte Hospital (Denmark); Mathias Prokop, Bram van Ginneken, Radboud Univ. Nijmegen Medical Ctr. (Netherlands)

We present a fully automatic method for the assessment of spiculation of pulmonary nodules in Computed Tomography (CT) images.

Spiculation is considered as one of the indicators of nodule malignancy and an important feature to assess when it comes to deciding on a patient-tailored follow-up procedure.

Presence of spiculation is a feature manually assessed by radiologists, therefore it is subject to inter- and intra-observer variability.

For these reasons, lung cancer screening scenario would benefit from the presence of a fully-automatic framework for the assessment of spiculation.

The presented framework relies on the fact that spiculated nodules mainly differ from non-spiculated nodules in their morphology. In order to discriminate the two categories, information on morphology is captured by sampling intensity profiles along circular patterns on spherical surfaces centred on the nodule, in a multi-scale fashion. Each intensity profile is interpreted as a periodic signal, where the Fourier transform is applied, obtaining a spectrum. A library of spectra is created and clustered via unsupervised learning.

The centroids of the clusters are used to label back each spectrum in the sampling pattern.

A compact descriptor encoding the nodule morphology is obtained as the histogram of labels along all the spheres and used to classify spiculated nodules via supervised learning using Random Forests classifier.

We tested our approach on a set of nodules from Danish Lung Cancer Screening Trial dataset.

Our results show that the proposed method outperforms state-of-the-art 3-D descriptors of morphology in the automatic assessment of spiculation.

9414-9, Session 2

Improving CAD performance by seamless insertion of pulmonary nodules in chest CT exams

Aria X. Pezeshk, Berkman Sahiner, Weijie Chen, Nicholas A. Petrick, U.S. Food and Drug Administration (United States)

The availability of large medical image datasets is critical in training and testing of computer aided diagnosis (CAD) systems. However, collection of data and establishment of ground truth for medical images are both costly and difficult. To address this problem, we have developed an image composition tool that allows users to modify or supplement existing datasets by seamlessly inserting a clinical lesion extracted from a source image into a different location on a target image. In this study we focus on the application of this tool to the training of a CAD system designed to detect pulmonary nodules in chest CT. We trained the CAD system on three sets of data. The first training set consisted of features extracted from original CT cases, the second set consisted of the first set plus features from nodules inserted into a new location, and the third set consisted of the first set plus features from nodules transformed in shape and contrast prior to insertion. We then compared the performance of the three CAD systems in differentiating nodules from normal areas by testing each trained system against a fixed dataset, and computing the area under the ROC curve (AUC). The performance of the systems trained with the augmented datasets was significantly better than that trained with the original dataset, with an improvement of up to 0.026 in AUC using the augmented datasets.

9414-10, Session 2

Analysis of the Vancouver lung nodule malignancy model with respect to manual and automated segmentation

Rafael Wiemker, Philips Research (Germany); Lilla Boroczky, Philips Research North America (United States); Martin Bergtholdt, Tobias Klinder, Philips Research (Germany)

The recently published Vancouver model for lung nodule malignancy prediction holds great promise as a practically feasible tool to mitigate the clinical decision problem of how to act on a lung nodule detected at baseline screening without interval growth information yet available. It provides a formula to compute a probability of malignancy from nine radiologically meaningful numerical and categorical features, which are provided by user interaction but could also be automatically pre-filled by appropriate image and text processing algorithms.

Nodule diameter is a feature with crucial influence on the predicted malignancy, and leads to uncertainty caused by inter-reader variability. We have analyzed the typical magnitude of the malignancy variability by applying the Vancouver malignancy model to 4238 consecutive nodules out of the public LIDC-IDRI database. This database provides up to four independent expert delineations for each nodule, so that the resulting Vancouver malignancy predictions can be compared. We have found a median variation of 1.8% absolute malignancy percent points caused by differing estimation of the longest nodule axis. It can be shown that using fully automatic nodule segmentation can significantly lower the variability of the malignancy probability computed by the Vancouver model, while showing excellent agreement with the expert readers. The automatic nodule segmentation used here is based on maximizing the weakest eigenvalue of the radial structure tensor.

9414-11, Session 2

Factors affecting uncertainty in lung nodule volume estimation with CT: comparisons of findings from two estimation methods in a phantom study

Qin Li, Marios A. Gavrielides, U.S. Food and Drug Administration (United States); Rongping Zeng, US Food and Drug Administration (United States); Kyle J. Myers, Berkman Sahiner, Nicholas A. Petrick, U.S. Food and Drug Administration (United States)

This work aimed to compare two different types of volume estimation methods in terms of identifying factors affecting measurement uncertainty. Twenty-nine synthetic nodules with varying size, radiodensity, and shape were placed in an anthropomorphic thoracic phantom and scanned with a 16-detector row CT scanner. Ten repeat scans were acquired using three exposures, two slice collimations, and were reconstructed with varying slice thicknesses. Nodule volumes were estimated from the reconstructed data using a matched-filter and a segmentation approach. Log transformed volumes were used to obtain measurement error with truth obtained through micro CT. ANOVA was applied to measurement error to identify significant factors affecting volume estimation for each method. Root mean square of measurement error (RMSE), repeatability coefficients (RC) and reproducibility coefficients (RDC) for different imaging conditions were evaluated. Results showed that for both methods, nodule size, shape and slice thickness were significant factors. Collimation was significant for the matched-filter method. RMSEs for matched-filter measurements were in general smaller than segmentation. To achieve RMSE on the order of 15% or less for {5, 8, 9, 10mm} nodules, the corresponding maximum allowable slice thicknesses were {3, 5, 5, 5mm} for the matched-filter and {0.8, 3, 3, 3mm} for the segmentation method. RCs increased with larger slice thicknesses for both methods. For 8-10mm nodules, the measurements were highly repeatable provided the slice thickness was ≤3mm and reproducible for thin collimation protocols, regardless of method and across varying acquisition conditions. These findings are valuable for validating lung nodule volume as a quantitative imaging biomarker.

9414-12, Session 3

Automatic machine learning based prediction of cardiovascular events in lung cancer screening data

Bob D. de Vos, Pim A. de Jong, Jelmer M. Wolterink, Univ. Medical Ctr. Utrecht (Netherlands); Rozemarijn Vliegenthart, Univ. of Groningen (Netherlands); Geoffrey Wielingen, Max A. Viergever, Ivana Isgum, Univ. Medical Ctr. Utrecht (Netherlands)

Calcium burden determined in CT images acquired in lung cancer screening is a strong predictor of cardiovascular events (CVEs). This study investigated whether subjects undergoing such screening who are at risk of a CVE can be identified using automatic image analysis and subject characteristics. Moreover, the study examined whether these individuals can be identified using solely image information, or if a combination of image and subject data is needed.

A set of 3559 male subjects undergoing Dutch-Belgian lung cancer screening trial was included. Low-dose non-ECG synchronized chest CT images acquired at baseline were analyzed (1834 scanned in the University Medical Center Groningen, 1725 in the University Medical Center Utrecht). Aortic and coronary calcifications were identified using previously developed automatic algorithms. A set of features describing number, volume and size distribution of the detected calcifications was computed. Age of participants was extracted from image headers. Features describing participants' smoking status, smoking history and past CVEs were obtained. CVEs that occurred within three years after the imaging were used as outcome.

Support vector machine classification was performed using only image features and subsequently, using a combination of image and subject related characteristics. Classification based solely on the image features resulted in the area under the ROC curve (Az) of 0.69. A combination of image and subject features resulted in Az of 0.71.

The results demonstrate that subjects undergoing lung cancer screening who are at risk of CVE can be identified using automatic image analysis. Adding subject information slightly improved the performance.

9414-13, Session 3

Automatic selection of best quality vessels from multiple-phase coronary CT angiography (cCTA)

Jordan Liu, Univ. of Michigan (United States); Lubomir M. Hadjiiski, Heang-Ping Chan, Chuan Zhou, Jun Wei, Aamer R. Chughtai, Jean W. Kuriakose, Ella A. Kazerooni, Univ. of Michigan Health System (United States)

We are developing an automated method to select the best-quality vessels of coronary arterial trees from multiple-phase cCTA and build a best-quality tree to facilitate the detection of stenotic plaques. Using our previously developed vessel registration method, the vessels from different phases were automatically registered. Branching points on the centerline are projected through the registered trees. The centerlines are split into branches based on the projected branching points. Each tree branch is then straightened. The registered trees and centerline branches are used to determine the correspondence of branches between phases so that each branch can be compared to its corresponding branches in the other phases. A vessel quality measure (VQM) is calculated as the average radial gradients at the vessel wall over the entire vessel branch. The quality of the corresponding branches from all phases is automatically compared using the VQM. An observer preference study was conducted with two radiologists to visually compare the quality of the vessels. Each radiologist, blinded to the VQM, evaluated pairs of corresponding branches that were automatically determined to be the best and worst quality by the VQM

and provided their preference. The agreement between the automatic selection and the radiologists' selections was evaluated using Cohen's kappa statistics. Between the first radiologist and the automated selection the result was k=0.87, between the second radiologist and the automated selection, k=0.80, and between the two radiologists, k=0.87. Our preliminary study demonstrates the feasibility of using an automated method to select the best-quality vessels from multiple cCTA phases.

9414-14, Session 3

Determining degree of optic nerve edema from fundus photography

Jason C. Agne, Jui-Kai Wang, The Univ. of Iowa (United States); Mona K. Garvin, The Univ. of Iowa (United States) and Iowa City VA Health Care System (United States); Randy H. Kardon, U.S. Dept. of Veterans Affairs (United States)

Swelling of the optic nerve head (ONH) is presently assessed through the Frisen Scale. It is believed that a direct measurement of the ONH volume would serve as a better representation of the swelling. However, a direct measurement would require segmentation of a 3D SD-OCT image, which is not always available. Here, we select features from more commonly available 2D fundus images and use them to predict ONH volume. Twenty-six features were extracted from each of 174 fundus images, of dimensions 2048x2392. The features include attributes of the blood vessels, optic nerve head, and periphery area. These features were used in a regression analysis to predict ONH volume, as computed by a segmentation of the SD-OCT image. The results of the classification yielded a mean square error of 2.34 mm3 and a correlation coefficient of R = 0:727, which suggests that ONH volume may be predicted from fundus features alone.

9414-15, Session 3

Automated segmentation of cardiac visceral fat in low-dose non-contrast chest CT images

Yiting Xie, Cornell Univ. (United States); Mingzhu Liang, David F. Yankelevitz, Claudia I. Henschke, Icahn School of Medicine at Mount Sinai (United States); Anthony P. Reeves, Cornell Univ. (United States)

Cardiac visceral fat was segmented from low-dose non-contrast chest CT images using a fully automated method. Cardiac visceral fat is defined as the fatty tissues surrounding the heart region, enclosed by the lungs and posterior to the sternum. The cardiac visceral fat is measured by first constraining the muscular heart region with an Anatomy Label Map that contains robust segmentations of the lungs and other major organs and estimating the fatty tissue within this region.

The algorithm was evaluated on 124 low-dose and 223 standard-dose non-contrast chest CT scans from two public datasets. Based on visual inspection, 343 cases had good cardiac visceral fat segmentation. For quantitative evaluation, manual markings of cardiac visceral fat regions were made in 3 image slices for 45 low-dose scans and the Dice similarity coefficient (DSC) was computed. The automated algorithm achieved an average DSC of 0.93. Cardiac visceral fat volume (CVFV), heart region volume (HRV) and their ratio were computed for each case. In addition, coronary artery calcification (CAC) and aortic calcification (AC) were measured in terms of the Agatston score (AS). Using linear regression R-squared correlation coefficient, CVFV was 0.76 correlated with CAC and 0.84 correlated with AC. The volume ratio was 0.61 correlated with CAC and 0.69 correlated with AC. Results indicated that cardiac visceral fat volume may be useful in the assessment of cardiovascular disease risk.

9414-16, Session 3

Development of a screening tool for staging of diabetic retinopathy in fundus images

Ashis K. Dhara, Sudipta Mukhopadhyay, Indian Institute of Technology Kharagpur (India); Mayur J. Bency, Indian Institute of Technology Indore (India); Rangaraj M. Rangayyan, Univ. of Calgary (Canada); Reema Bansal, Post Graduate Institute of Medical Education and Research, Chandigarh (India); Amod Gupta, Post Graduate Institute of Medical Education and Research (India)

Diabetic retinopathy is a condition of the eye of diabetic patients where the retina is damaged because of long-term diabetes. The condition deteriorates towards irreversible blindness in extreme cases of diabetic retinopathy. Hence, early detection of diabetic retinopathy is important to prevent blindness. Regular screening of fundus images of diabetic patients could be helpful in preventing blindness caused by diabetic retinopathy. In this paper, we propose techniques for staging of diabetic retinopathy in fundus images using several shape and texture features computed from detected microaneurysms, exudates, and hemorrhages. The classification accuracy is reported in terms of the area (Az) under the receiver operating characteristic curve using 200 fundus images from the MESSIDOR database. The value of Az for classifying normal images versus combination of mild, moderate, and severe NPDR is 0.9106. The value Az for classification of mild NPDR versus combination of moderate and severe NPDR is 0.9110. The Az value for classification of moderate NPDR and severe NPDR is 0.9750.

9414-17, Session 4

Segmentation of the whole breast from low-dose chest CT Images

Shuang Liu, Cornell Univ. (United States); Mary Salvatore, David F. Yankelevitz, Claudia I. Henschke, Mount Sinai School of Medicine (United States); Anthony P. Reeves, Cornell Univ. (United States)

The segmentation of the whole breast serves as the first step towards automated breast lesion detection. It is also necessary for automatically assessing the breast density, which is considered to be an important risk factor for breast cancer. In this paper we present a fully automated algorithm to segment the whole breast in low-dose chest CT images (LDCT), which has been recommended as an annual lung cancer screening test. The automated whole breast segmentation and potential breast density readings as well as lesion detection in LDCT will provide useful information for women who have received LDCT screening, especially the ones who have not undergone mammographic screening, by providing them additional risk indicators for breast cancer with no additional radiation exposure. The two main challenges to be addressed are significant range of variations in terms of the shape and location of the breast in LDCT and the separation of pectoral muscles from the glandular tissues. The presented algorithm achieves robust whole breast segmentation using an anatomy directed rule-based method. The evaluation is performed on 20 LDCT scans by comparing the segmentation with ground truth manually annotated by a radiologist on one axial slice and two sagittal slices for each scan. The resulting average Dice coefficient is 0.880 with a standard deviation of 0.058, demonstrating that the automated segmentation algorithm achieves results consistent with manual annotations of a radiologist.

9414-18, Session 4

Vessel segmentation in screening mammograms

Jan-Jurre Mordang, Nico Karssemeijer, Radboud Univ. Medical Ctr. (Netherlands)

Blood vessels are a major cause of false positives in computer aided detection systems for the detection of breast cancer. Therefore, the purpose of this study is to construct a framework for the segmentation of blood vessels in screening mammograms. The proposed framework is based on supervised learning using a cascade classifier. This cascade classifier consists of several stages where in each stage a GentleBoost classifier is trained on Haar-like features. A total of 30 cases were included in this study. In each image, vessel pixels were annotated by selecting pixels on the centerline of the vessel, control samples were taken by annotating a region without any visible vascular structures. This resulted in a total of 31,000 pixels marked as vascular and over 4 million control pixels. After training, the classifier assigns a vesselness likelihood to the pixels. The proposed framework was compared to three other vessel enhancing methods, i) a vesselness filter, ii) a gaussian derivative filter, and iii) a tubeness filter. The methods were compared in terms of area under the receiver operating characteristics curves, the Az values. The Az value of the cascade approach is 0.85. This is superior to the vesselness, Gaussian, and tubeness methods, with Az values of 0.77, 0.81, and 0.78, respectively. From these results, it can be concluded that our proposed framework is a promising method for the detection of vessels in screening mammograms.

9414-19, Session 4

Comparison of computer-aided detection of clustered microcalcifications in digital mammography and digital breast tomosynthesis

Ravi K. Samala, Heang-Ping Chan, Yao Lu, Lubomir M. Hadjiiski, Jun Wei, Mark A. Helvie, Univ. of Michigan (United States)

Digital breast tomosynthesis (DBT) has the potential to replace digital mammography (DM) for breast cancer screening. Comparison of computer-aided detection (CAD) of microcalcification clusters (MCs) on DM and DBT is essential to this transition. In this study, we collected a data set with corresponding DBT and DM for the same breasts. DBT was acquired with IRB approval and informed consent using a GE GEN2 DBT prototype system and the DM acquired with GE Essential system for the patient's clinical care was collected retrospectively from patient files. DM-based CAD (CADDM) and DBT-based CAD (CADDBT) were previously developed by our group. The major differences between the CAD systems include: (a) CADDBT uses two parallel processes whereas CADDM uses a single process for enhancing MCs and background removal, (b) CADDBT has additional processing steps to reduce the false positives (FPs), including ranking of candidates of cluster seeds and cluster members and the use of adaptive CNR and size thresholds at clustering and FP reduction, (c) CADDM uses convolution neural network (CNN) and linear discriminant analysis (LDA) to differentiate true microcalcifications from FPs based on their morphological and CNN features. The performance difference is assessed by FROC analysis using test set (100 views with MCs and 74 views without MCs) independent of their respective training sets. At sensitivities of 70% and 80%, CADDBT achieved FP rates of 0.78 and 1.57 per view compared to 0.66 and 2.10 per image for the CADDM. JAFROC showed no significant difference between MC detection on DM and DBT by the two CAD systems.

9414-21, Session 4

Signal enhancement ratio (SER) quantified from breast DCE-MRI and breast cancer risk

Shandong Wu, Univ. of Pittsburgh School of Medicine (United States); Brenda F. Kurland, Univ. of Pittsburgh (United States); Wendie A. Berg, Margarita L. Zuley, Univ. of Pittsburgh School of Medicine (United States) and Magee-Womens Hospital (United States); Rachel C. Jankowitz, Univ. of Pittsburgh School of Medicine (United States) and Magee-Womens Hospital (United States); Jules Sumkin, Univ. of Pittsburgh School of Medicine (United States) and Magee-Womens Hospital (United States); David Gur, Univ. of Pittsburgh School of Medicine (United States)

Breast magnetic resonance imaging (MRI) is recommended as an adjunct to mammography for women who are considered at high risk of developing breast cancer. As a key component of breast MRI, dynamic contrast-enhanced MRI (DCE-MRI) uses a contrast agent to provide high intensity contrast between breast tissues, making it sensitive to tissue composition and vascularity. Breast DCE-MRI characterizes certain physiologic properties of breast tissue that are potentially related to breast cancer risk. Studies have shown that increased background parenchymal enhancement (BPE), which is the contrast enhancement occurring in normal cancer-unaffected breast tissues in post-contrast sequences, predicts increased breast cancer risk. Signal enhancement ratio (SER) computed from pre-contrast and post-contrast sequences in DCE-MRI measures change in signal intensity due to contrast uptake over time and is a measure of contrast enhancement kinetics. SER quantified in breast tumor has been shown potential as a biomarker for characterizing tumor response to treatments. In this work we investigated the relationship between quantitative measures of SER and breast cancer risk. A retrospective case-control study was performed using a cohort of 102 women, consisting of 51 women who had newly diagnosed unilateral breast cancer and 51 matched controls with a unilateral biopsy-proven benign lesion. SER was quantified using fully automated computerized algorithms and three SER-derived quantitative volume measures were compared between the cancer cases and controls using logistic regression analysis. Our results show that SER is predictive of risk, even after adjustment for BI-RADS-based mammographic breast density. This indicates that SER has potential for use as a risk factor for breast cancer risk assessment in high-risk women.

9414-22, Session 4

A comparative analysis of 2D and 3D CAD for calcifications in digital breast tomosynthesis

Raymond J. Acciavatti, The Univ. of Pennsylvania Health System (United States); Shonket Ray, Univ. of Pennsylvania (United States); Brad M. Keller, Univ. of Pennsylvania School of Medicine (United States); Andrew D. A. Maidment, Emily F. Conant, The Univ. of Pennsylvania Health System (United States)

Many medical centers offer digital breast tomosynthesis (DBT) and 2D digital mammography acquired under the same compression (i.e., "Combo" examination) for screening. This paper compares a conventional 2D CAD algorithm (Hologic® ImageChecker® CAD v9.4) for calcification detection against a prototype 3D algorithm (Hologic® ImageChecker® 3D Calc CAD v1.0). Due to the newness of DBT, the development of this 3D algorithm is on-going, and it is currently not FDA-approved in the United States. For this study, DBT screening cases with suspicious calcifications were identified retrospectively at the University of Pennsylvania. An expert radiologist (EFC) reviewed images with both 2D and DBT CAD marks, and compared the marks to biopsy results. Control cases with one-year negative follow-up were also studied; these cases either possess clear benign calcifications or lack calcifications. To allow the user to alter the sensitivity for cancer detection, an operating point is assigned to each CAD mark. As expected from conventional 2D CAD, increasing the operating point in 3D CAD yields increased sensitivity and reduced specificity. Additionally, we showed that some cancers are occult to 2D CAD at all operating points. By contrast, 3D CAD allows for detection of some cancers that are missed on 2D CAD. We also demonstrated that some non-cancerous CAD marks in 3D are not present at analogous locations in the 2D image. Hence, there are additional marks when using both 2D and 3D CAD in combination, leading to lower specificity than with conventional 2D CAD alone.

9414-23, Session 4

A superpixel-based framework for automatic tumor segmentation on breast DCE-MRI

Ning Yu, The Univ. of Pennsylvania Health System (United States); Jia Wu, Univ. of Pennsylvania (United States); Susan P. Weinstein, The Univ. of Pennsylvania Health System (United States); Bilwaj K. Gaonkar, Univ. of Pennsylvania (United States); Brad M. Keller, Univ. of Pennsylvania School of Medicine (United States); Ahmed B. Ashraf, The Univ. of Pennsylvania Health System (United States); YunQing Jiang, Univ. of Pennsylvania (United States); Christos A. Davatzikos, Emily F. Conant, Despina Kontos, The Univ. of Pennsylvania Health System (United States)

Accurate and efficient automated tumor segmentation in breast dynamic contrast-enhanced magnetic resonance imaging (DCE-MRI) is highly desirable for computer-aided tumor diagnosis. We propose a novel automatic segmentation framework which incorporates mean-shift smoothing, superpixel-wise classification, pixel-wise graph-cuts partitioning, and morphological refinement. A set of 15 breast DCE-MR images obtained from the American college of radiology imaging network (ACRIN) 6657 I-SPY trial, a prospective clinical trial evaluating MR imaging for prediction of response to neoadjuvant chemotherapy, were manually segmented to generate tumor masks (as ground truth) and breast masks (as regions of interest). Four state-of-the-art segmentation approaches based on diverse models were also utilized for comparison. Based on five standard evaluation metrics for segmentation, the proposed framework consistently outperformed all other approaches. The performance of the proposed framework was: 1) 0.83 for Dice similarity coefficient, 2) 0.96 for pixel-wise accuracy, 3) 0.72 for VOC score, 4) 1.12 pixels for mean absolute difference, and 5) 16.66 pixels for maximum Hausdorff distance, which surpassed the second best method (i.e., adaptive geodesic transformation), a semi-automatic algorithm depending on precise initialization. Our results suggest promising potential applications of our segmentation framework in assisting analysis of breast carcinomas.

9414-42, Session 4

Initial experience with computer aided detection for microcalcification in digital breast tomosynthesis

Elaine F Harkness, Ctr. for Imaging Sciences, The Univ. of Manchester (United Kingdom) and Nightingale and Genesis Prevention Ctr., Univ. Hospital of South Manchester (United Kingdom); Yit Y. Lim, Mary W.

Wilson, Rabea Haq, Jin Zhou, Catriona Tate, Nightingale and Genesis Prevention Ctr., Univ. Hospital of South Manchester (United Kingdom); Anthony J. Maxwell, Nightingale and Genesis Prevention Ctr., Univ. Hospital of South Manchester (United Kingdom) and Ctr. for Imaging Sciences, The Univ. of Manchester (United Kingdom) and Manchester Cancer Research Ctr., The Univ. of Manchester (United Kingdom); Susan M. Astley, Centre for Imaging Sciences, The Univ. of Manchester (United Kingdom) and Nightingale and Genesis Prevention Ctr., Univ. Hospital of South Manchester (United Kingdom) and Manchester Cancer Research Ctr., The Univ. of Manchester (United Kingdom); Fiona J. Gilbert, School of Clinical Medicine, Univ. of Cambridge (United Kingdom)

Purpose

Digital breast tomosynthesis (DBT) addresses limitations of 2-D projection imaging for the detection of masses in dense breasts. Microcalcification clusters may be more difficult to appreciate in DBT as individual calcifications within a cluster may appear on different slices. An accurate computer aided detection (CAD) system for microcalcification could overcome this difficulty. This research aims to evaluate the performance of ImageChecker 3D Calc CAD v1.0 for the detection of microcalcification clusters.

Methods

Women were recruited from screening assessment and family history clinics as part of the multicentre TOMMY trial. 169 DBT images were processed with the CAD algorithm. All cases were confirmed on histology. Three consultant radiologists reviewed the images and recorded the location of each calcification cluster, slice numbers and whether CAD prompts were on or off target.

Results

79/80 (98.8%) malignant cases had a prompt on the area of microcalcification. In these cases, there were 1-15 marks (median 5) with the majority of false prompts (n=326/438) recorded as benign (68%) and vascular (24%) calcifications. Of 89 normal cases, there were 1-13 prompts/case (median 3), 27 (30%) had no prompts and the majority of false prompts (n=238) were benign (77%) and vascular (14%) calcifications.

Conclusion

CAD is effective in prompting malignant microcalcification clusters and may overcome the difficulty of detecting clusters in slice images. Although there was a high rate of false prompts, most of these can readily be dismissed as benign/normal. Further advances in the software may improve specificity.

9414-24, Session 5

Connection method of separated luminal regions of intestine from CT volumes

Masahiro Oda, Nagoya Univ. (Japan); Takayuki Kitasaka, Aichi Institute of Technology (Japan); Kazuhiro Furukawa, Osamu Watanabe, Takafumi Ando, Nagoya Univ. Graduate School of Medicine (Japan); Yoshiki Hirooka, Nagoya Univ. (Japan); Hidemi Goto, Nagoya Univ. Graduate School of Medicine (Japan); Kensaku Mori, Nagoya Univ. (Japan)

This paper proposes a connection method of separated luminal regions of the intestine for Crohn's disease diagnosis. Crohn's disease is an inflammatory disease of the digestive tract. A capsule or endoscopic diagnosis is performed for Crohn's disease diagnosis. However, parts of the intestines may not be observed in the endoscopic diagnosis if intestinal stenosis occurs. Endoscopes cannot pass through the stenosed parts. CT image-based diagnosis is developed as an alternative choice of the Crohn's disease. CT image-based diagnosis enables physicians to observe the entire intestines even if stenosed parts exist. CAD systems for Crohn's disease using CT volumes are recently developed. Such CAD systems need to reconstruct separated luminal regions of the intestines to analyze intestines. We propose a connection method of separated luminal regions of the intestines segmented from CT volumes. The luminal regions of the intestines are segmented from a CT volume. The centerlines of the luminal regions are calculated by using a thinning process. We enumerate all the possible sequences of the centerline segments. In this work, we newly introduced a condition using distance between connected ends points of the centerline segments. This condition eliminates unnatural connections of the centerline segments. After generating a sequence list of the centerline segments, the correct sequence obtained by using an evaluation function. We connect the luminal regions based on the correct sequence. Our experiments using four CT volumes showed that our method connected 6.5 out of 8.0 centerline segments per case.

9414-25, Session 5

Electronic cleansing for dual-energy CT colonography based on material decomposition and virtual monochromatic imaging

Rie Tachibana, Janne J. Näppi, Massachusetts General Hospital (United States); Se Hyung Kim, Seoul National Univ. Hospital (Korea, Republic of); Hiroyuki Yoshida, Massachusetts General Hospital (United States)

CT colonography (CTC) uses orally administered fecal tagging to enhance retained fluid and feces that could otherwise obscure or imitate polyps. To visualize the complete region of colon without residual materials, electronic cleansing (EC) can be used to perform virtual subtraction of the fecal-tagged materials from CTC images. However, conventional EC methods produce subtraction artifacts and may fail to subtract unclearly tagged feces. We developed a novel EC method that uses dual-energy CT colonography (DE-CTC) to improve the EC performance. In our method, two-material decomposition is performed to calculate water-iodine decomposition images. A k-nearest neighbors (k-NN) classification method is used to analyze the water-iodine decomposition to identify regions of lumen air, soft tissue, and tagged materials in the images. Virtual monochromatic (VM) images are calculated from the water-iodine decomposition at four energy levels, after which the VM images are used to classify the colonic materials further into partial-volume interfaces. Finally, cleansed images are generated by subtraction of the labeled images from observed CTC images. For pilot evaluation, we employed fecal-tagged DE-CTC data of an anthropomorphic phantom and 10 clinical DE-CTC cases. Preliminary results suggest that the EC method are effective in subtracting feces that are difficult to remove in conventional EC methods such as thin tagging layers on the colonic wall, as well as in preserving thin soft-tissue structures and air-tissue-tagging layers that tend to be erroneously removed in conventional EC methods. The new EC method is promising in virtually cleansing of the colon without producing subtraction artifacts.

9414-26, Session 5

Distance weighted 'inside disc' classifier for computer-aided diagnosis of colonic polyps

Yifan Hu, Stony Brook Univ. (United States); Bowen Song, Zhengrong Liang, Stony Brook Medicine (United States); Perry J. Pickhardt, Univ. of Wisconsin-Madison (United States)

Feature classification plays an important role in computer-aided diagnosis (CADx) of suspicious lesions. As one of the simplest machine learning algorithms, the k-NN classifier has been widely used in many classification problems. However, the k-NN has a drawback that the majority class

will dominate the prediction of a new sample. To mitigate the drawback, efforts have been devoted to set weight on each neighbor to avoid the influence of this "majority" and various weighted or wk-NN strategies have been explored. In this paper, we explored a different strategy of "distance weighted inside disc" (DWID), which classifies the test point by assigning a corresponding label with consideration of those points inside the disc whose center is the test point, instead of the k-nearest points, like k-NN and wk-NN did. We evaluated this new DWID algorithm with comparison to the k-NN, wk-NN, support vector machine (SVM) and random forest (RF) classifiers by experiments on a database of 153 lesions (polyps), including 116 neoplastic lesions and 37 hyperplastic lesions. The results were documented quantitatively by the Receiver Operating Characteristics (ROC) analysis and the merit of area under the ROC curve (AUC), which is a well-established evaluation criteria to various classifiers. The experiments showed noticeable gain by this new classifier according to the AUC values, as compared to the k-NN and wk-NN, as well as the SVM and RF. In the meantime, this new algorithm also showed a noticeable reduction of computing time.

9414-27, Session 5

Efficient Hilbert transform-based alternative to Tofts physiological models for representing MRI dynamic contrast-enhanced images in computer-aided diagnosis of prostate cancer

Kevin M. Boehm, Shijun Wang, Karen E. Burtt, Baris Turkbey, Samuel Weisenthal, Peter A. Pinto, Peter L. Choyke, Bradford J. Wood, National Institutes of Health (United States); Nicholas A. Petrick, Berkman Sahiner, U.S. Food and Drug Administration (United States); Ronald M. Summers, National Institutes of Health (United States)

In computer-aided diagnosis (CAD) systems for prostate cancer, dynamic contrast enhanced (DCE) magnetic resonance imaging is useful for distinguishing cancerous and benign tissue. The Tofts physiological model is a commonly used representation of the DCE image data, but the parameters require extensive computation. Hence, we developed an alternative representation based on the Hilbert transform of the DCE images. The time maximum of the Hilbert transform, a binary metric of early enhancement, and a pre-DCE value was assigned to each voxel and appended to a standard feature set derived from T2-weighted images and apparent diffusion coefficient maps. A cohort of 40 patients was used for training the classifier, and 20 patients were used for testing. The AUC was calculated by pooling the voxel-wise prediction values and comparing with the ground truth. The resulting AUC of 0.92 (95% CI [0.87 0.97]) is not significantly different from an AUC calculated using Tofts physiological models of 0.92 (95% CI [0.87 0.97]), as validated by a Wilcoxon signed rank test on each patient's AUC (p = 0.19). The time required for calculation and feature extraction is 11.39 seconds (95% CI [10.95 11.82]) per patient using the Hilbert-based feature set, two orders of magnitude faster than the 1319 seconds (95% CI [1233 1404]) required for the Tofts parameter-based feature set (p<0.001). Hence, the features proposed herein appear useful for CAD systems integrated into clinical workflows where efficiency is important.

9414-28, Session 5

The evaluation of multi-structure, multi-atlas pelvic anatomy features in a prostate MR lymphography CAD system

Midas Meijs, Oscar Debats, Henkjan Huisman, Radboud Univ. Nijmegen Medical Ctr. (Netherlands)

In prostate cancer the detection of metastatic lymph nodes indicates progression from localized disease to metastasized cancer. The detection of positive lymph nodes is, however, a complex and time-consuming task for experienced radiologists. Assistance of a two-stage Computer-Aided-Detection (CAD) system in MR Lymphography (MRL) is not yet feasible due to the large amount of false positives in the first stage of the system. By introducing a multi-structure, multi-atlas segmentation, using an affine transformation followed by a B-spline transformation for registration, the organ location is given by a mean density probability map. The atlas segmentation is semi-automatically drawn with ITK-SNAP, using Active Contour Segmentation. Each anatomic structure is identified by a label number. Registration is performed using Elastix, using Mutual Information and an Adaptive Stochastic Gradient optimization. The dataset consists of ten patient scans with lymph nodes manually annotated in consensus by two expert readers. The feature-map of the CAD system consists of the Multi-Atlas and various other features (e.g Normalized-Intensity and multi-scale Blobness). The voxel based Gentleboost classifier is evaluated using ROC analysis with cross-validation. We show in a set of 10 studies that adding multi-structure, multi-atlas anatomical structure likelihood features improves the quality of the lymph node voxel likelihood map. Multiple structure anatomy maps may thus make MRL CAD more feasible.

9414-29, Session 6

Role of machine learning in clinical decision support *(Keynote Presentation)*

Tanveer F. Syeda-Mahmood, IBM Research - Almaden (United States)

With the advent of new machine learning techniques, the field of automated clinical decision support is poised for a new growth. Previously, the decision support systems have been predominantly rule-based and built on fixed pre-determined associations from clinical knowledge. The IBM AALIM system pioneered a new direction in evidence-based medicine using the concept of patient similarity and exploiting consensus opinions of other physicians who have looked at similar patients. It proposed the fundamental idea that similar clinical data points to similar patients and therefore to similar recommendations for diagnosis, treatment and outcome. This led to a scalable learning-driven way of doing clinical decision support where associations between diseases and their manifestations in modality data were learned automatically through patient similarity methods. With the advent of deep learning methods, learning-based decision support can now be combined with clinical knowledge-driven techniques to define the next generation of clinical decision support systems.

In this talk, I will discuss the role of learning techniques in decision support giving examples from practical multimodal decision support systems. I will also describe the IBM Medical Sieve Radiology Grand Challenge, a worldwide collaborative research effort across IBM research labs that is expanding patient data and knowledge-driven learning methods to define new clinical decision support systems for radiologists.

9414-30, Session 6

Deep learning with non-medical training used for chest pathology identification

Yaniv Bar, Tel-Aviv Univ. (Israel); Idit Diamant, Lior Wolf, Hayit Greenspan, Tel Aviv Univ. (Israel)

In this work, we examine the strength of deep learning approaches for pathology detection in chest radiograph data. Convolutional neural networks (CNN) deep architecture classification approaches have gain popularity due to their ability to learn mid and high level image representations. We explore the ability of CNN learned from a non-medical dataset to identify different types of pathologies in chest x-ray images. We tested our algorithm on a dataset of 93 images. The best performance was achieved using a combination of features extracted from CNN and a set of low-level features. We obtained an area under curve (AUC) of 0.93 for Right Pleural Effusion detection, 0.89 for Enlarged heart detection and

0.79 for classification between healthy and abnormal chest x-ray, where all pathologies are combined into one large class. The results demonstrate the feasibility of detecting pathology in chest x-ray using deep learning approaches based on non-medical learning. This is a first-of-its-kind experiment that shows that Deep learning with ImageNet, a large scale non-medical image database may be sufficient for general medical image recognition tasks.

9414-31, Session 6

Texture classification of anatomical structures in CT using a context-free machine learning approach

Oscar A. Jiménez del Toro, HES-SO Valais (Switzerland) and Univ. de Genève (Switzerland); Antonio Foncubierta Rodríguez, HES-SO Valais (Switzerland); Adrien Depeursinge, Henning Müller, HES-SO Valais (Switzerland) and Univ. de Genève (Switzerland)

Annotating anatomical structures in medical images is a time consuming task for radiologists. This classification cannot be scaled to the amount and complexity of medical images produced daily in clinical routine. Computer-based approaches help exploit this information contained in medical images by numerically measuring and quantifying specific visual features. Many segmentation approaches are currently available to classify varying anatomical structures. However, these methods are often organ-specific and their implementation is not scalable for larger datasets of different modalities and body parts. A context-free anatomical multi-structure classification method is proposed that does not require a global initialization and can automatically learn the most representative texture patterns from a wide range of anatomical structures. The implementation combines state-of-the-art methods such as 3D Riesz texture feature quantification and a bag of visual words. The proposed method is tested using a leave-one-patient-out approach with 30 computed tomography volumes. An overall accuracy of 76% is obtained for 8 classes of 10 anatomical structures. The improved classification and clustering of the different textures obtained with the proposed method could be used for more in-depth automatic image analysis based on data-driven objective measurements.

9414-32, Session 6

Multi-test cervical cancer diagnosis with missing data estimation

Tao Xu, Xiaolei Huang, Lehigh Univ. (United States); Edward Kim, Villanova Univ. (United States); L. Rodney Long, Sameer K. Antani, National Library of Medicine (United States)

Cervical cancer is the third most common type of cancer for women worldwide. Existing screening programs for cervical cancer suffer from low sensitivity. Using images of the cervix (cervigrams) as an aid in detecting pre-cancerous changes to the cervix has good potential to improve sensitivity and help reduce the number of cervical cancer cases. In this paper, we present a method that utilizes multi-modality information extracted from multiple tests of a patient's visit to classify the patient visit to be either low-risk or high-risk. Our algorithm integrates image features and text features to make a diagnosis. We also present two strategies to estimate the missing values in text features: Image Classifier Supervised Mean Imputation (ICSMI) and Image Classifier Supervised Linear Interpolation (ICSLI). We evaluate our method on a large medical dataset and compare it with several alternative approaches. The results show that the proposed method with ICSLI strategy achieves the best result of 83.03% specificity and 76.36% sensitivity. When higher specificity is desired, our method can achieve 90% specificity with 62.12% sensitivity.

9414-33, Session 7

Atlas-based segmentation of brainstem regions in neuromelanin-sensitive magnetic resonance images

Marc Puigvert, Clínica Univ. de Navarra (Spain); Gabriel Castellanos, Javier Uranga, Univ. de Navarra (Spain); Ricardo Abad, Clínica Univ. de Navarra (Spain); María A. Fernández-Seara, Pablo Pastor, María A. Pastor, Arrate Muñoz-Barrutia, Carlos Ortiz de Solórzano, Univ. de Navarra (Spain)

We present a method for the automatic delineation of two neuromelanin rich brainstem structures –substantia nigra pars compacta and locus coeruleus- in neuromelanin sensitive magnetic resonance images of the brain. The segmentation method uses a dynamic multi-image reference atlas and a pre-registration atlas selection strategy. To create the atlas, a pool of 35 images of healthy subjects was pair-wise pre-registered and clustered in groups using an affinity propagation approach. Each group of the atlas is represented by a single exemplar image. Each new target image to be segmented is registered to the exemplars of each cluster. Then all the images of the highest performing clusters are enrolled into the final atlas, and the results of the registration with the target image are propagated using a majority voting approach. All registration processes used combined one two-stage affine and one elastic B-spline algorithm, to account for global positioning, region selection and local anatomic differences. In this paper, we present the algorithm, with emphasis in the atlas selection method and the registration scheme. We evaluate the performance of the atlas selection strategy using 35 healthy and 5 Parkinson's subjects. Then, we quantified the volume and contrast ratio of neuromelanin signal of these structures in 47 normal and 40 Parkinson's subjects to confirm that this method can detect neuromelanin loss in Parkinson's disease patients and could eventually be used for the early diagnosis of this disease.

9414-34, Session 7

Automatic anatomy recognition in post-tonsillectomy MR images of obese children with OSAS

Yubing Tong, Jayaram K. Udupa, Dewey Odhner, Univ. of Pennsylvania (United States); Sanghun Sin, Raanan Arens, Children's Hospital at Montefiore (United States)

Automatic Anatomy Recognition (AAR) is a recently developed approach for the automatic whole body wide organ segmentation. We previously tested that methodology on image cases with some pathology where the organs were not distorted significantly. In this paper, we present an advancement of AAR to handle organs which may have been modified or resected by surgical intervention. We focus on MRI of the neck in pediatric Obstructive Sleep Apnea Syndrome. The proposed method consists of an AAR step followed by Support Vector Machine techniques to detect the presence/absence of organs. The AAR step employs a hierarchical organization of the organs for model building. For each organ a fuzzy model over a population is built. The model of the body region is then described in terms of the fuzzy models and a host of other descriptors which include parent to offspring relationship estimated over the population. Organs are recognized following the organ hierarchy by using an optimal threshold based search. The SVM step subsequently checks for evidence of presence of organs. The preliminary results show that AAR techniques can be combined with machine learning strategies within the AAR recognition framework for good performance in recognizing missing organs, in our case missing tonsils in post-tonsillectomy images. The previous recognition performance is maintained achieving an organ localization accuracy of within 1 voxel when the organ is actually not removed. To our knowledge, no methods have been reported to date for handling significantly deformed or missing organs, especially in neck MRI.

SPIE. MEDICAL IMAGING

9414-35, Session 7

Multi-fractal detrended texture feature for brain tumor classification

Syed M. S. Reza, Randall Mays, Khan M. Iftekharuddin, Old Dominion Univ. (United States)

We propose a novel non-invasive brain tumor type classification using Multi-fractal Detrended Fluctuation Analysis (MFDFA) [1] in structural magnetic resonance (MR) images. In this work, we investigate the efficacy of the MFDFA features along with our novel texture feature known as multi-fractional Brownian motion (mBm) [2] in classifying (grading) brain tumors as High Grade (HG) and Low Grade (LG). Based on prior performance, Random Forest (RF) [3] is employed for tumor grading using two different datasets such as BRATS-2013 [4] and BRATS-2014 [5]. Quantitative scores such as percentage of cases correctly classified (CCR) and area under the curve (AUC) from the receiver operating characteristics (ROC) curve are obtained. On an average 81% to 83% of CCR and 73% to 80% of AUC from the inter-dataset cross-validation confirm the efficacy of the proposed method.

9414-36, Session 7

Small white matter lesion detection in cerebral small vessel disease

Mohsen Ghafoorian, Radboud Univ. Nijmegen (Netherlands); Nico Karssemeijer, Radboud Univ. Nijmegen (Netherlands) and Radboud Univ. Nijmegen Medical Ctr. (Netherlands); Inge van Uden, Donders Institute for Brain, Cognition and Behaviour, Radboud University Medical Center (Netherlands); Frank-Erik de Leeuw, Radboud Univ. Nijmegen Medical Ctr. (Netherlands); Tom Heskes, Radboud Univ. Nijmegen (Netherlands); Elena Marchiori, Radboud Univ. Jijmegen (Netherlands); Bram Platel, Radboud Univ. Nijmegen Medical Ctr. (Netherlands)

Small Vessel Disease (SVD) is a common finding on Magnetic Resonance Images of elderly people. White matter lesions (WML) are important markers for not only small vessel disease, but also other neuro-degenerative diseases including multiple sclerosis, Alzheimer and vascular dementia. Volumetric measurements such as the "total lesion load", have been studied and related to these diseases. With respect to SVD we conjecture that small lesions are important, as they have been observed to grow over time. To study these small lesions they need to be annotated, which is a complex and time-consuming task. Existing (semi)automatic methods have been aimed at volumetric measurements and large lesions, and are not suitable for the detection of small lesions.

In this research we established a supervised voxel classification CAD system, optimized and trained to exclusively detect small WMLs. To achieve this, several preprocessing steps were taken, which included a robust standardization of subject intensities to reduce inter-subject intensity variability as much as possible. A number of features that were found to be well identifying small lesions were calculated including multimodal intensities, tissue probabilities, several features for accurate location description, a number of second order derivative features as well as multi-scale annular filter for blobness detection. Only small lesions were used to learn the target concept via Adaboost using random forest as its basic classifier. Finally the results were evaluated using Free-response receiver operating characteristic (FROC).

9414-37, Session 7

Automated prediction of tissue outcome after acute ischemic stroke in computed tomography perfusion images

Pieter C. Vos, Image Sciences Institute (Netherlands); Edwin Bennink, Hugo W. A. M. de Jong, Birgitta K. Velthuis, Max A. Viergever, Jan Willem Dankbaar, Univ. Medical Ctr. Utrecht (Netherlands)

Assessment of the extent of cerebral damage on admission in patients with acute ischemic stroke could play an important role in treatment decision making. CT-perfusion (CTP) imaging can be used to determine the extent of damage. However, clinical application is hindered by differences among vendors and used methodology. As a result, threshold based methods and visual assessment of CTP images has not yet shown to be useful in treatment decision making and predicting clinical outcome. Primarily results in MR studies have shown the benefit of using supervised classifiers for predicting tissue outcome, but this has not been demonstrated for CTP. We present a novel method for the automatic prediction of tissue outcome by combining multi-parametric CTP images into a tissue outcome probability map. A supervised classification scheme was developed that extracts absolute and relative perfusion values from CTP images which are summarized by a trained classifier into a likelihood of infarction. Training was performed using follow-up CT scans of 20 acute stroke patients with complete recanalization of the vessel that was occluded on admission. Infarcted regions were annotated by expert neuroradiologists. Multiple classifiers were evaluated in a leave-one-patient-out strategy for their discriminating performance using ROC statistics. Results showed that a RandomForest classifier performed optimally with an area under the ROC of 0.90 for discriminating infarct tissue. The obtained results are an improvement over existing thresholding methods and are in line with results found in literature where MR perfusion was used.

9414-38, Session 7

Automated segmentation of thyroid gland on CT images with multi-atlas label fusion and random classification forest

Jiamin Liu, Kevin Chang, Lauren Kim, Evrim B. Turkbey, Le Lu, Jianhua Yao, National Institutes of Health (United States)

The thyroid gland plays an important role in clinical practice, especially for radiation therapy treatment planning. For patients with head and neck cancer, radiation therapy requires a precise delineation of the thyroid gland to be spared on the pre-treatment planning CT images to avoid thyroid dysfunction. In the current clinical workflow, the thyroid gland is normally manually delineated by radiologists or radiation oncologists, which is time consuming and error prone. Therefore, a system for automated segmentation of the thyroid is desirable. However, automated segmentation of the thyroid is challenging because the thyroid is inhomogeneous and surrounded by structures that have similar intensities. In this work, the thyroid gland segmentation is initially estimated by multi-atlas label fusion algorithm. The segmentation is refined by supervised statistical learning based voxel labeling with a random forest algorithm. Multi-atlas label fusion (MALF) transfers expert-labeled thyroids from atlases to a target image using deformable registration. Errors produced by label transfer are reduced by label fusion that combines the results produced by all atlases into a consensus solution. Then, random forest (RF) employs an ensemble of decision trees that are trained on labeled thyroids to recognize features. The trained forest classifier is then applied to the thyroid estimated from the MALF by voxel scanning to assign the class-conditional probability. Voxels from the expert-labeled thyroids in CT volumes are treated as positive classes; background non-thyroid voxels as negatives. We applied this automated thyroid segmentation system to CT scans of 20 patients. The results showed that the MALF achieved an overall 0.75 Dice Similarity Coefficient (DSC) and the RF classification further improved the DSC to 0.81.

9414-39, Session 7

Detection of Alzheimer's disease using group lasso SVM-based region selection

Zhuo Sun, Leiden Univ. Medical Ctr. (Netherlands); Yong Fan, Institute of Automation (China); Boudewijn P. F. Lelieveldt, Martijn van de Giessen, Leiden Univ. Medical Ctr. (Netherlands)

In the last two decades, structural magnetic resonance imaging (MRI) has shown potential in distinguishing Alzheimer's disease patients and elderly controls (CN).

To obtain AD-specific biomarkers, which is very useful in understanding the disease, previous research used either statistical testing to find statistically significant different regions between the two clinical groups, or lasso to select isolated features in the image domain. In this paper, we propose a new framework that uses structural MRI to simultaneously distinguish the two clinical groups and find the bio-markers of AD, using a group lasso SVM. The group lasso term introduces the anatomical information from image domain into feature domain, so the resulting set of selected voxels are more meaningful than the lasso SVM. Because of large inter-structure size variation, we introduce a group specific normalization factor to deal with the structure size bias. Experiments have been performed on a well AD vs. CN designed dataset to validate our method. Comparing to the lasso sparse SVM approach, our method achieved better classification performance and a more meaningful biomarker selection. When we vary the training sets the selected regions by our method were more stable than the lasso SVM. Classification experiments showed that our group normalization lead to higher classification accuracy with fewer selected regions than non-normalized method. Comparing to the state-of-art AD vs. CN classification methods, our approach not only obtains a high accuracy in the same dataset, more importantly, we simultaneously find the brain anatomies that are closely related to the disease.

9414-20, Session 8

Local breast density as a predictor of breast cancer

Mayu Otsuka, Univ. of Manchester Medical School (United Kingdom); Elaine F. Harkness, Ctr. for Imaging Sciences, The Univ. of Manchester (United Kingdom) and Nightingale Ctr. and Genesis Prevention Ctr., Univ. Hospital of South Manchester (United Kingdom) and Manchester Academic Health Science Ctr., The Univ. of Manchester (United Kingdom); Xin Chen, Ctr. for Imaging Sciences, The Univ. of Manchester (United Kingdom) and Manchester Academic Health Science Ctr. (United Kingdom); Emmanouil Moschidis, Ctr. for Imaging Sciences, Institute of Population Health, The Univ. of Manchester (United Kingdom) and Manchester Academic Health Science Ctr. (United Kingdom); Megan Bydder, Nightingale Ctr. and Genesis Prevention Ctr., Univ. Hospital of South Manchester, NHS (United Kingdom); Soujanya Gadde, Nightingale Ctr. and Genesis Prevention Ctr., Univ. Hospital of South Manchester (United Kingdom); Yit Y. Lim, Ctr. for Imaging Sciences, Institute of Population Health, The Univ. of Manchester (United Kingdom) and Nightingale Ctr. and Genesis Prevention Ctr., Univ. Hospital of South Manchester (United Kingdom); Anthony J. Maxwell, Ctr. for Imaging Sciences, The Univ. of Manchester (United Kingdom) and Nightingale Ctr. and Genesis Prevention Ctr., Univ. Hospital of South Manchester (United Kingdom) and Manchester Breast Ctr., Manchester Cancer Research Ctr. (United Kingdom); Anthony Howell, Nightingale Ctr. and Genesis Prevention Ctr., Univ. Hospital of South Manchester (United Kingdom) and Manchester Breast Ctr., Manchester Cancer Research Ctr. (United Kingdom); Paula Stavrinos, Univ. Hospital of South Manchester (United Kingdom) and The Univ. of Manchester, Manchester Academic Health Science Centre (United Kingdom); Mary Wilson, Nightingale Ctr. and Genesis Prevention Ctr., Univ. Hospital of South Manchester (United Kingdom); Susan M. Astley, Ctr. for Imaging Sciences, The Univ. of Manchester (United Kingdom) and Univ. Hospital of South Manchester (United Kingdom) and Manchester Breast Ctr., Manchester Cancer Research Ctr., Christie Hospital (United Kingdom)

Introduction:

High overall breast density is associated with increased risk of developing cancer, and risk of cancers being masked by dense tissue. We investigate local density at the site of cancer in diagnostic images, in corresponding previous full-field digital screening mammograms taken before cancer was detected, and in matched controls.

Methods:

Volpara volumetric breast density maps were obtained for 54 mammograms in which unilateral breast cancer was detected and corresponding previous digital screening mammograms which had been read as normal. These were matched to 3 controls on age, menopausal status, HRT use, BMI and year of previous mammogram. Local percent density was computed in 15mm square regions at lesion sites and corresponding locations in other images. Conditional logistic regression was used to predict case-control status.

Results:

In diagnostic and previous screening mammograms, local breast density was significantly increased at the lesion site compared with a similar location in the opposite breast (medians 21.58%, 9.18%, p<0.001 diagnostic; 18.82%, 9.45%, p<0.001 previous). Women in the highest tertile of local density in previous mammograms were significantly more likely to develop breast cancer than those in the lowest (OR 42.09, 95%CI: 5.37-329.94). Those in the highest tertile of Volpara gland volume were also more likely to develop cancer (OR 2.89, 95%CI: 1.30-6.42).

Conclusion:

Local breast density is increased at sites where cancer will develop in the future compared with corresponding regions in the opposite breast and matched controls. The detection of localised increases in breast density could enhance computer-aided detection of early breast cancer.

9414-40, Session 8

Identifying metastatic breast tumors using textural kinetic features of a contrast based habitat in DCE-MRI

Baishali Chaudhury, Mu Zhou, Dmitry B. Goldof, Lawrence O. Hall, Univ. of South Florida (United States); Robert A. Gatenby, Robert J. Gillies, Jennifer S. Drukteinis, H. Lee Moffitt Cancer Ctr. & Research Institute (United States)

The ability to distinguish aggressive tumors from indolent tumors using quantitative image analysis on dynamic contrast enhanced magnetic resonance imaging (DCE-MRI) would dramatically change the breast cancer treatment paradigm. With this prognostic information, patients with more aggressive tumors that have the propensity to spread to distant sites outside of the breast could be selected for more aggressive treatment. Conversely, patients with tumors that do not have the propensity to metastasize could be treated less aggressively, avoiding some of the morbidity associated with surgery, radiation and chemotherapy. We propose a computer aided diagnosis (CAD) framework to identify which

breast cancers will metastasize to the loco-regional lymph nodes as well as which tumors will eventually go on to develop distant metastases using quantitative image analysis and radiomics. We defined a new contrast based tumor habitat and analyzed textural kinetic features from this habitat for classification purposes. Initially, intra-tumor segmentation is performed on both initial contrast uptake and delayed washout patterns within the tumor, generating intensity based tumor habitats. Subsequently, fusion of the tumor habitats with high initial uptake and rapid washout is performed to extract the habitat of interest.

We analyzed twenty-seven representative image slices from volumetric DCE-MRI of breast tumors, for classifying tumors with lymph node metastases from tumors without lymph node metastases. For this an accuracy of 80.6% was achieved using 3 features. Twenty of the twenty-seven patients were analyzed for classification of distant metastatic disease from tumors without lymph node metastases, accuracy was 84.3% using 5 features.

9414-43, Session 8

Digital breast tomosynthesis: application of 2D digital mammography CAD to detection of microcalcification clusters on planar projection image

Ravi K. Samala, Heang-Ping Chan, Yao Lu, Lubomir M. Hadjiiski, Jun Wei, Mark A. Helvie, Univ. of Michigan (United States)

Computer-aided detection (CAD) has the potential to aid radiologists in detection of microcalcification clusters (MCs). CAD for digital breast tomosynthesis (DBT) can be developed for the reconstructed volumes, the projection views or other derivatives. We have developed a novel method of generating a single planar projection (PPJ) image from a regularized DBT volume to emphasize the high contrast objects like microcalcifications while suppressing the anatomical background and noise. In this work we adapted a CAD system developed for digital mammography (CADDM) to the PPJ image and compared its performance with our CAD system developed for DBT volumes (CADDBT) in the same set of cases. The background removal preprocessing step in CADDM was not needed for PPJ. With a training set, parameter optimization was performed while the methods and processing steps were kept without modification. The linear discriminant analysis classifier using cluster based features was retrained to generate a discriminant score to be used as decision variable. For view-based FROC analysis, at 80% sensitivity, an FP rate of 1.95/volume and 1.54/image were achieved, respectively, for CADDBT and CADDM in an independent test set. At a threshold of 1.2 FPs/image or volume, the nonparametric analysis for significance testing shows that the optimized CADDM for PPJ is significantly better than CADDBT. However, the performance of CADDM drops at higher sensitivity or FP rate, resulting in similar overall performance between the two CAD systems. A joint CAD system combining detection in the DBT volume and the PPJ image has the potential to increase the sensitivity and reduce the FP rate.

9414-44, Session 8

Combination of conspicuity improved synthetic mammograms and digital breast tomosynthesis: a promising approach for mass detection

Seong Tae Kim, Dae Hoe Kim, Yong Man Ro, KAIST (Korea, Republic of)

In this study, a novel mass detection framework that utilizes the information from synthetic mammograms has been developed for detecting masses in digital breast tomosynthesis (DBT). In clinical study, it is demonstrated that the combination of DBT and full field digital mammography (FFDM)

increases the reader performance. To reduce the radiation dose in this approach, synthetic mammogram has been developed in previous researches and it is demonstrated that synthetic mammogram can alternate the FFDM when it is used with DBT. In this study, we investigate the feasibility of the combined approach of DBT and synthetic mammogram in point of computer-aided detection (CAD). The mass likelihood scores estimated for each mass candidates in synthetic mammogram and DBT are merged to differentiate masses and false positives (FPs) in combined approach. We compared the performance of detecting masses in the proposed combined approach and DBT alone. A clinical data set of 196 DBT volumes was used to evaluate the different detection schemes. The combined approach achieved sensitivity of 80% and 89% with 1.16 and 2.37 FPs per DBT volume. The DBT alone approach achieved same sensitivities with 1.61 and 3.46 FPs per DBT volume. Experimental results show that statistically significant improvement (p = 0.002) is achieved in combined approach compared to DBT alone. These results imply that the information fusion of synthetic mammogram and DBT is a promising approach to detect masses in DBT.

9414-76, Session 8

Association of mammographic image feature change and an increasing risk trend of developing breast cancer: an assessment

Maxine Tan, The Univ. of Oklahoma (United States); Joseph K. Leader, Univ. of Pittsburgh (United States); Hong Liu, Bin Zheng, The Univ. of Oklahoma (United States)

We recently investigated a new mammographic image feature based risk factor to predict near-term breast cancer risk after a woman has a negative mammographic screening. We hypothesized that unlike the conventional epidemiology-based long-term (or lifetime) risk factors, the mammographic image feature based risk factor value will increase as the time lag between the negative and positive mammography screening decreases. The purpose of this study is to test this hypothesis. From a large and diverse full-field digital mammography (FFDM) image database with 1278 cases, we collected all available sequential FFDM examinations for each case including the "current" and 1 to 3 most recently "prior" examinations. All prior examinations were interpreted negative, and current ones were either malignant or recalled negative/benign. We computed 91 global mammographic texture and density based features, and included three clinical risk factors (woman's age, family history and subjective breast density BI-RADS ratings). On this initial feature set, we applied a fast and accurate Sequential Forward Floating Selection (SFFS) feature selection algorithm to reduce feature dimensionality. The features computed on both mammographic views were individually/separately trained using two artificial neural network (ANN) classifiers. The classification scores of the two ANNs were then merged with a sequential ANN. The results show that the maximum adjusted odds ratios were 5.59, 7.98, and 15.77 for using the 3rd, 2nd, and 1st "prior" FFDM examinations, respectively, which demonstrates a higher association of mammographic image feature change and an increasing risk trend of developing breast cancer in the near-term after a negative screening.

9414-46, Session 9

Multimodal classification of prostate tissue: a feasibility study on combining multiparametric MRI and ultrasound

Hussam A. Ashab, Nandinee F. Haq, Guy Nir, Piotr Kozlowski, The Univ. of British Columbia (Canada); Peter Black, UBC (United States); Edward Jones, S. Larry Goldenberg, Tim E. Salcudean, The Univ. of British Columbia (Canada); Mehdi Moradi, The Univ. of British

Columbia (Canada) and IBM Research Almaden (United States)

Multiparametric MRI (mpMRI) is a powerful technique to determine the need for prostate biopsy and for targeting the tumor. The common practice for biopsy guidance is through transrectal ultrasound, with registration of the MRI-based targets when available. Even though previous work shows the potential utility of ultrasound, and particularly ultrasound vibro-elastography, as a tissue typing approach, ultrasound has only been used as a guidance modality in MR-targeted ultrasound-guided biopsy. We argue that vibro-elastography images could contain information that is not captured using mpMRI and therefore play a role in refining the biopsy and treatment strategies. In this work, we combine mpMRI with multiparametric B-mode and vibro-elastography ultrasound features from registered tissue areas to examine the potential improvement in cancer detection. All the images are acquired prior to radical prostatectomy and cancer detection is validated based on 36 whole mount histology slides. We calculated a set of 24 texture features from vibro-elastography and B-mode images and performed recursive feature elimination (RFE) and sparse regression through LASSO to find an optimal set of ultrasound features to be used along with mpMRI features. We show that the set of these selected features increases the area under ROC curve from 0.87 with mpMRI alone to 0.95 with mpMRI and ultrasound, when used with support vector machine classification in the peripheral zone cancer detection. For whole-gland cancer detection, the area under the curve was 0.75 and 0.82 for mpMRI and mpMRI along with ultrasound, respectively. These preliminary results provide evidence that ultrasound and ultrasound vibro-elastography could be used as modalities for improved cancer detection in combination with MRI.

9414-47, Session 9

Towards intraoperative surgical margin assessment and visualization using bioimpedance properties of the tissue

Shadab Khan, Aditya Mahara, Thayer School of Engineering at Dartmouth (United States); Elias S. Hyams, Alan R. Schned, Dartmouth Hitchcock Medical Ctr. (United States); Ryan J. Halter, Thayer School of Engineering at Dartmouth (United States)

Prostate cancer (PCa) has a high 10-year recurrence rate, making PCa the second leading cause of cancer-specific mortality among men in the USA. PCa recurrences are often predicted by assessing the status of surgical margins (SM) – positive surgical margins (PSM) increase the chances of biochemical recurrence by 2-4 times which may lead to PCa recurrence. To this end, an SM assessment system using Electrical Impedance Spectroscopy (EIS) was developed with a microendoscopic probe. This system measures the tissue bioimpedance over a range of frequencies (1 kHz to 1MHz), and computes a Composite Impedance Metric (CIM). CIM can be used to classify tissue as benign or cancerous. The system was used to collect the impedance spectra from excised prostates, which were obtained from men undergoing radical prostatectomy. The data revealed statistically significant (p<0.05) differences in the impedance properties of the benign and tumorous tissues, and between different tissue morphologies. To visualize the results of SM-assessment, a visualization tool using da Vinci stereo laparoscope is being developed. Together with the visualization tool, the EIS-based SM assessment system can be potentially used to intraoperatively classify tissues and display the results on the surgical console with a video feed of the surgical site, thereby augmenting a surgeon's view of the site and providing a potential solution to the intraoperative SM assessment needs.

9414-48, Session 9

Quantification, validation, and follow up of small bowel motility in Crohn's disease

Juan J. Cerrolaza, Children's National Medical Ctr. (United States); Jennifer Q. Peng, Princeton Univ. (United States) and Children's National Health System (United States); Nabile M. Safdar, Children's National Health System (United States); Laurie Conklin, Children's National Health System (United States); Raymond W. Sze, Children's National Medical Ctr. (United States); Marius George Linguraru, Children's National Medical Ctr. (United States) and The George Washington Univ. (United States)

The use of magnetic resonance enterography (MRE) has become a mainstay in the evaluation, assessment and follow up of inflammatory bowel diseases, such as Crohn's disease (CD), thanks to its high image quality and its non-ionizing nature. In particular, the advent of faster MRE sequences less sensitive to image-motion artifacts offers the possibility to obtain visual structural and functional information of the patient's small bowel. However, the inherent subjectivity of the mere visual inspection of these images often hinders the accurate identification and monitoring of the affected areas. In this paper, we present a new framework that provides quantitative and objective motility information of the small bowel from free-breathing MRE dynamic sequences. After compensating for the breathing motion of the patient, we create personalized peristaltic activity maps via optical flow analysis. The result is a new framework that allows the creation of a new set of images providing objective and precise functional information of the small bowel. The accuracy of the new method was also evaluated from two different perspectives: objective accuracy (1.1 ±0.6 mm/s), i.e., the ability of the system to provide real information about the velocity of moving bowel landmarks, and subjective accuracy (0.7±0.7 in a range of 1 to 5), i.e., the degree of agreement with the subjective evaluation of an expert. Finally, the practical utility of the new method was successfully evaluated in a preliminary study with 32 studies, showing its potential for the fast and accurate assessment and follow up of CD.

9414-49, Session 9

A content-based image retrieval method for optical colonoscopy images based on image recognition techniques

Hirokazu Nosato, Hidenori Sakanashi, Eiichi Takahashi, Masahiro Murakawa, National Institute of Advanced Industrial Science and Technology (Japan)

This paper proposes a content-based image retrieval method for optical colonoscopy images that can find images similar to ones being diagnosed. Optical colonoscopy is directly observation method for colon and rectum to diagnose bowel diseases. It is the most popular procedure for screening, surveillance and treatment. However, diagnostic accuracy of intractable inflammatory bowel diseases such as ulcerative colitis (UC) is highly dependent on the experience and knowledge of the medical doctor because there is immense variety in the appearances of colonic mucosa in inflammatory with UC. In order to solve this issue, this paper proposes a content-based image retrieval method based on image recognition techniques. The proposed retrieval method can find similar images from the database of the diagnosed as UC, and then it is expected to furnish the medical records associated with retrieved image to assist UC diagnosis. In the proposed method, histogram features and higher order local auto-correlation (HLAC) features are adopted to represent color information and geometrical information of the optical colonoscopy images, respectively. In addition, considering the characteristics of UC colonoscopy images, such as vascular pattern and roughness of colonic mucosa, we also propose the image enhancement method to highlight the appearances of colonic mucosa with UC. In the experiment using 161 UC images which were taken

from 32 patients, we demonstrate that our method improves the accuracy of the retrieval of similar UC images.

9414-50, Session 9

Detection of colonic polyp candidates with level set-based thickness mapping over the colon wall

Hao Han, Stony Brook Medicine (United States); Lihong C. Li, College of Staten Island (United States); Chaijie Duan, Graduate School at Shenzhen, Tsinghua Univ. (United States); Yang Zhao, Stony Brook Medicine (United States); Huafeng Wang, Beihang Univ. (China); Zhengrong Liang, Stony Brook Medicine (United States)

The improvement of computer-aided detection of colonic polyps is vital to advance computed tomographic colonography (CTC) toward a screening modality. Detection of small, especially flat, polyps is challenging because limited image features can be extracted from such polyps. In this paper, we present a novel scheme to automatically detect initial polyp candidates (IPCs), especially flat polyps, in CTC images. First, tagged materials in CTC images were automatically removed via our previously developed electronic colon cleansing (ECC) strategy. Coupled level sets method was then used to segment the volumetric colon wall from CTC images after ECC. Furthermore, we introduced a CT density integral metric along the electric field line tracing direction defined by both inner and outer colon wall surfaces as an indicator for colon lesions. The integral was computed from each voxel on the outer-most serosal layer to the inner-most mucosal layer. By considering the partial volume effect between colon lumen and wall, the proposed integral metric was designed to model a complete local environment near the volumetric colon wall where the to-be-detected colonic polyps reside. To help radiologists visualize the IPC detection result, a three-dimensional patient-specific colon wall model was constructed based on segmented colon wall, and density integral values were color mapped to each voxel on the colon wall surface. The proposed IPC detection approach was validated on patient CTC scans with annotated flat polyps, and the method was effective to determine large density integral regions where polyps are present in the ground truth.

9414-106, Session 9

Characterization of aggressive prostate cancer using ultrasound RF time series

Amir Khojaste, Farhad Imani, Queen's Univ. (Canada); Mehdi Moradi, The Univ. of British Columbia (Canada); David Berman, D. Robert Siemens, Eric E. Sauerberi, Alexander H. Boag, Kingston General Hospital (Canada); Purang Abolmaesumi, The Univ. of British Columbia (Canada); Parvin Mousavi, Queen's Univ. (Canada)

Prostate cancer is the most prevalently diagnosed and the second cause of cancer-related death in North American men. Several approaches have been proposed to augment detection of prostate cancer using different imaging modalities. Due to advantages of ultrasound imaging, these approaches have been the subject of several recent studies. This paper presents the results of a feasibility study on differentiating between lower and higher grade prostate cancer using ultrasound RF time series data. We also propose new spectral features of RF time series to highlight aggressive prostate cancer in small ROIs of size 1 mm x 1 mm in a cohort of 19 ex vivo specimens of human prostate tissue. The current method shows promising results on differentiating between lower and higher grade of prostate cancer using ultrasound RF time series.

9414-51, Session 11

Automated measurement of pulmonary artery in low-dose non-contrast chest CT images

Yiting Xie, Cornell Univ. (United States); Mingzhu Liang, David F. Yankelevitz, Claudia I. Henschke, Icahn School of Medicine at Mount Sinai (United States); Anthony P. Reeves, Cornell Univ. (United States)

A new measurement of the pulmonary artery diameter is obtained where the artery may be robustly segmented between the heart and the artery bifurcation. An automated algorithm is presented that can make this pulmonary artery measurement in low-dose non-contrast chest CT images. The algorithm uses a cylinder matching method following geometric constraints obtained from other adjacent organs that have been previously segmented. This new measurement and the related ratio of pulmonary artery to aortic artery measurement are compared to traditional manual approaches for pulmonary artery characterization.

The algorithm was qualitatively evaluated on 124 low-dose and 223 standard-dose non-contrast chest CT scans from two public datasets; 324 out of the 347 cases had good segmentations and in the other 23 cases there was significant boundary inaccuracy. For quantitative evaluation, the comparison was to manually marked pulmonary artery boundary in an axial slice in 45 cases; the resulting average Dice Similarity Coefficient was 0.88 (max 0.95, min 0.74). For the 45 cases, the automated pulmonary artery to ascending aorta diameter ratio was 0.96 correlated with the manually measured ratio at pulmonary artery bifurcation level using linear regression R-squared correlation coefficient. This automated measurement may have utility as an alternative to the conventional manual measurement of pulmonary artery diameter at the bifurcation level especially in the context of noisy low-dose CT images.

9414-52, Session 11

Quantitative analysis of arterial flow properties for detection of non-calcified plaques in ECG-gated coronary CT angiography

Jun Wei, Chuan Zhou, Heang-Ping Chan, Aamer R. Chughtai, Prachi Agarwal, Jean W. Kuriakose, Lubomir M. Hadjiiski, Smita Patel, Ella A. Kazerooni, Univ. of Michigan Health System (United States)

We are developing a CADe system to assist radiologists in detection of NCPs in coronary CTA (cCTA). In this study, we applied quantitative analysis of arterial flow properties to each vessel branch. Under rest conditions, blood flow in a single vessel branch was assumed to follow Poiseuille's law. For a uniform pressure distribution, two quantitative flow features, the normalized arterial compliance per unit length (Cu) and the normalized volumetric flow (Q) along the vessel centerline, were calculated based on the parabolic Poiseuille solution. NCP candidates were identified and luminal analysis was designed to extract 14 geometric and gray level features. The flow features were added to the feature space to differentiate NCPs from FPs. A data set of 87 cCTA scans was retrospectively collected from 87 patient files with IRB approval. A total of 123 NCPs were identified by experienced radiologists. The correlation between the two flow features was 0.31. The area under the ROC curve (AUC) was 0.656 for Cu and 0.608 for Q in comparison to 0.537-0.625 for our previous luminal features. The detection performance was evaluated with 10-fold cross validation. Applying feature selection to only the training subset for each fold, the most frequently selected features included the two flow features and two luminal features. With FROC analysis, the test results indicated a reduction of the FP rates to 3.11, 2.22, and 1.30 FPs/scan at sensitivities of 90%, 80%, and 70%, respectively. The study indicated that quantitative blood flow analysis was useful for FP reduction in detection of NCPs.

9414-53, Session 11

Automated age-related macular degeneration classification in OCT using unsupervised feature learning

Freerk G. Venhuizen, Bram van Ginneken, Mark J. van Grinsven, Bart Bloemen, Rick H. H. M. Philipsen, Radboud Univ. Nijmegen Medical Ctr. (Netherlands); Carel B. Hoyng, Radboud Univ. Nijmegen (Netherlands); Thomas Theelen, Clarisa I. Sánchez, Radboud Univ. Nijmegen Medical Ctr. (Netherlands)

Age-related Macular Degeneration (AMD) is a common eye disorder with high prevalence in elderly people. The disease mainly affects the central part of the retina, and could ultimately lead to permanent vision loss. Optical Coherence Tomography (OCT) is becoming the standard imaging modality in diagnosis of AMD and the assessment of its progression. However, the evaluation of the obtained volumetric scan is time consuming, expensive and the signs of early AMD are easy to miss. We propose a classification method to automatically distinguish AMD patients from healthy subjects with high accuracy. The method is based on an unsupervised feature learning approach, and processes the complete image without the need for an accurate pre-segmentation of the retina. The method can be divided in two steps: an unsupervised clustering stage that extracts a set of small descriptive image patches from the training data, and a supervised training stage that uses these patches to create a patch occurrence histogram for every image on which a random forest classifier is trained. Experiments using 384 volume scans show that the proposed method is capable of identifying AMD patients with high accuracy, obtaining an area under the Receiver Operating Curve of 0.984. Our method allows for a quick and reliable assessment of the presence of AMD pathology in OCT volume scans without the need for accurate layer segmentation algorithms.

9414-54, Session 11

Automatic discrimination of color retinal images using the bag of words approach

Ibrahim Sadek I. Hussein Tahoun, Désiré Sidibé, Fabrice Meriaudeau, Univ. de Bourgogne (France)

Diabetic retinopathy (DR) and age related macular degeneration (ARMD) are among the major causes of visual impairment worldwide. DR is mainly characterized by small red spots, namely microaneurysms and bright lesions, specifically exudates. However, ARMD is mainly identified by tiny yellow or white deposits called drusen. Since exudates might be the only visible signs of the early diabetic retinopathy, there is an increase demand for automatic retinopathy diagnosis. Exudates and drusen may share similar appearances; as a result discriminating between them plays a key role in improving screening performance. In this research, we investigative the role of bag of words approach in the automatic diagnosis of retinopathy diabetes. Initially, the color retinal images are preprocessed in order to reduce the intra and inter patient variability. Subsequently, SURF (Speeded up Robust Features), HOG (Histogram of Oriented Gradients), and LBP (Local Binary Patterns) descriptors are extracted from retinal images. We proposed to use single-based and multiple-based methods to construct the visual dictionary by combining the histogram of word occurrences from each dictionary and building a single histogram. Finally, this histogram representation is fed into a support vector machine with a linear kernel for classification. The introduced approach is evaluated for automatic diagnosis of normal and abnormal color retinal images with bright lesions such as drusen and exudates. This approach has been implemented on 430 color retinal images, including six publicly available datasets, in addition to one local dataset. The mean accuracies achieved are 97.2% and 99.77% for single-based and multiple-based dictionaries respectively.

9414-55, Session 12

Reducing annotation cost and uncertainty in computer-aided diagnosis through selective iterative classification

Amelia R. Riely, The Univ. of North Carolina at Chapel Hill (United States); Kyle J. Sablan, San Diego State Univ. (United States); Thomas Xiaotao, Jacob D. Furst, Daniela S. Raicu, DePaul Univ. (United States)

Advances in medical imaging technology have expanded the need for Computer-Aided Diagnosis (CAD) systems to assist radiologists in analyzing image data. However, where there is no ground truth diagnosis, experts in CAD systems often turn to multiple annotations to approximate a reference truth. Especially in the medical field, each of these annotations is expensive, and may not necessarily add to the quality of the classification model. This paper outlines a selective iterative CAD system to minimize the number of annotations required to obtain desirable accuracy, by requesting additional labels only for cases that could benefit from them. This approach simultaneously increases accuracy over a non-selective system, since it reduces noise and uncertainty in the labels. In the case of the LIDC dataset, our results show that using only 46.91% of the original label set, we can achieve 81.17% accuracy, as opposed to only 70.86% when 100% labels are used.

9414-56, Session 12

A computer-aided diagnosis system to identify regions of pathologic change in temporal subtraction images of the chest

Charles Ho, Rice Univ. (United States); Katherine Lee, Purdue Univ. (United States); Samuel G. Armato III, The Univ. of Chicago (United States)

Radiologists often compare sequential radiographs side-by-side in order to identify regions of change and evaluate the clinical significance of such regions. Some changes in pathology, however, may be overlooked or misinterpreted. For this reason, temporal subtraction (TS) images provide an important tool for enhanced visualization. Not all areas of "change" demonstrated on a TS image are caused by pathology. The purpose of this study, therefore, was to develop an automated computer-aided diagnosis (CAD) system that attempts both to locate regions of change as well as to classify such regions as being true regions of pathologic change as opposed to false regions of change caused by misregistration artifacts (i.e., differences in patient positioning). The dataset used in this study contained 120 images, within which an experienced radiologist outlined 74 regions of true pathologic change that were used as the gold standard. Through gray-level thresholding and initial false-positive reduction, an initial set of candidates was extracted and inputted to a classifier. A five-fold cross-validation method was employed to create training and testing groups. Both false candidate regions as well as the gold standard regions were used as training data. Of the three classifiers that were tested (support vector machine, logistic regression, and linear discriminant analysis), the logistic regression classifier performed the best with a sensitivity of 96% and specificity of 84%. Receiver operating characteristic (ROC) analysis of this classifier resulted in an area under the ROC curve of 0.94. These results show promise in the performance of the CAD system to detect regions of pathologic changes in TS images of the chest.

9414-57, Session 12

Exploring new quantitative CT image features to improve assessment of lung cancer prognosis

Nastaran Emaminejad, University of Oklahoma (United States); Wei Qian, The Univ. of Texas at El Paso (United States); Yan Kang, Northeastern Univ. (China); Yubao Guan, Guangzhou Medical College (China); Fleming Lure, University of Texas (United States); Bin Zheng, The Univ. of Oklahoma (United States)

Although stage I non-small-cell lung cancers usually have favorable prognosis, a high percentage of patients have cancer relapse after surgery. To optimally treat cancer patients to minimize the risk of cancer relapse and reduce mortality rates, it requires developing more accurate and reliable biomarkers or tools to predict cancer prognosis. In this study, we developed and tested a new computer-aided detection scheme to segment lung tumors and compute a set of quantitative image features from the chest X-ray CT images, which include the maximum tumor diameter, 3D tumor volume, average density of tumor volume and boundary. We then computed the association of each image feature with two patient outcome indices namely, Disease Free Survival (DFS) and Overall Survival (OS). Using a testing dataset involving 68 cases, the data analysis results showed that the tumor density features (including the average density inside the tumor volume or along the tumor boundary) had highest correlation with both DFS and OS (>0.45), while the computed tumor volume and/or tumor size measured by the radiologists based on RECIST guideline had much lower correlation with DFS and OS (<0.15). In addition, the correlation of the image features also had lower correlation (<0.32) with a popular lung cancer genetic biomarker, ERCC1. This study demonstrated that using quantitative tumor image features provide significantly higher prediction power than the tumor size and it is also possible to develop the multi-variable classifiers that fuse both image and genetic biomarkers to achieve more accurate and reliable results in assessing cancer prognosis.

9414-58, Session 12

Nonlinear dimensionality reduction of CT histogram based feature space for predicting recurrence-free survival in non-small-cell lung cancer

Yoshiki Kawata, Noboru Niki, Univ. of Tokushima (Japan); Hironobu Ohamatsu, Keiju Aokage, Masahiko Kusumoto, Takaaki Tsuchida, National Cancer Ctr. Hospital East (Japan); Kenji Eguchi, Teikyou Univ. School of Medicine (Japan); Masahiro Kaneko, Tokyo Health Service Association (Japan)

Research results from the National Lung Screening Trial (NLST) revealed that screening for lung cancer with low-dose CT (LDCT) reduces lung cancer mortality in heavy smokers by 20% compared to radiography. In the implementation of LDCT screening for lung cancer, the overdiagnosis and the occurrence of cancer recurrence after curative surgery of nodules detected at an early stage have been becoming crucial issues. Therefore, the identification of patients with early-stage lung cancer who have a higher risk for recurrence and who require more aggressive surveillance or who may benefit from adjuvant therapy has been a target of intense investigation. Computer-aided prognosis has been shown to be feasible for predicting patient and disease outcome via quantitative CT image analyses. We have described a quantitative five-category (α, β, y, n̄, and ε) classification based on CT value histogram analysis that has the potential to provide more detailed information on the potential aggressiveness of individual NSCLC nodules. In the five-category classification, we found that the use of two features, frequency of the highest peak of the CT histogram and 90th

percentile, is an appropriate combination for representing the pulmonary distribution. In this study, we postulated that manifold learning and non-linear dimensionality reduction could map from the two-dimensional (2D) space to the target real line which represents risk score to predict the likelihood of recurrence-free survival (RFS) for patients with non-small cell lung cancer (NSCLC). Using these scores, we developed a multivariate model with a stepwise modeling approach based on piecewise linear Cox proportional hazards regression model. We assessed the prognostic and predictive efficacy of the model by calculating time-dependent concordance index.

9414-59, Session 12

Computer-aided detection of lung cancer: combining pulmonary nodule detection systems with a tumor risk prediction model

Arnaud Arindra Adiyoso Setio, Colin Jacobs, Radboud Univ. Nijmegen Medical Ctr. (Netherlands); Francesco Ciompi, Radboud Univ. Nijmegen (Netherlands); Sarah J. van Riel, Radboud Univ. Nijmegen Medical Ctr. (Netherlands); Mathilde M. Winkler Wille, Asger Dirksen, Gentofte Hospital (Denmark); Eva M. van Rikxoort, Bram van Ginneken, Radboud Univ. Nijmegen Medical Ctr. (Netherlands)

Computer-Aided Detection (CAD) has been shown to be a promising tool for automatic detection of pulmonary nodules from computed tomography (CT) images. However, the vast majority of detected nodules are benign and do not require any treatment. For effective implementation of lung cancer screening programs, accurate identification of malignant nodules is the key. We investigate strategies to improve the performance of a CAD system in detecting nodules with a high probability of being cancers. Two strategies were proposed: combining CAD detections with a recently published lung cancer risk prediction model and the combination of multiple CAD systems. First, CAD systems were used to detect the nodules. Each CAD system produces markers with a certain degree of suspicion. Next, the malignancy probability was automatically computed for each marker, given nodule characteristics measured by the CAD system. Last, CAD degree of suspicion and malignancy probability were combined using the product rule. We evaluated the method using 62 nodules which were proven to be malignant cancers, from 180 scans of the Danish Lung Cancer Screening Trial. The malignant nodules were considered as positive samples, while all other findings were considered negative. Using a product rule, the best proposed system achieved an improvement in sensitivity, compared to the best individual CAD system, from 41.9% to 72.6% at 2 false positives (FPs)/ scan and from 56.5% to 88.7% at 8 FPs/scan. Our experiment shows that combining a nodule malignancy probability with multiple CAD systems can increase the performance of computerized detection of lung cancer.

9414-60, Session 13

Pneumothorax detection in chest radiographs using local and global texture signatures

Ofer Geva, Gali Zimmerman Moreno, Tel Aviv Univ. (Israel); Sivan Lieberman, Eli Konen, Sheba Medical Ctr. (Israel); Hayit Greenspan, Tel Aviv Univ. (Israel)

A novel framework for automatic detection of pneumothorax abnormality in chest radiographs is presented. The suggested method is based on a texture analysis approach combined with supervised learning techniques. The proposed framework consists of two main steps: at first, a texture analysis process is performed for detection of local abnormalities. Labeled

image patches are extracted in the texture analysis procedure following which local analysis values are incorporated into a novel global image representation. The global representation is used for training and detection of the abnormality at the image level. The presented global representation is designed based on the distinctive shape of the lung, taking into account the characteristics of typical pneumothorax abnormalities. A supervised learning process was performed on both the local and global data, leading to trained detection system. The system was tested on a dataset of 108 upright chest radiographs. Several state of the art texture feature sets were experimented with (Local Binary Patterns, Maximum Response filters). The optimal configuration yielded sensitivity of 81% with specificity of 87%. The results of the evaluation are promising, establishing the current framework as a basis for additional improvements and extensions.

9414-61, Session 13

Computer-aided detection of bladder mass within contrast-enhanced region of CTU

Kenny H. Cha, Lubomir M. Hadjiiski, Heang-Ping Chan, Elaine M. Caoili, Richard H. Cohan, Chuan Zhou, Univ. of Michigan (United States)

We are developing a computer-aided detection system for bladder cancer on CTU. The bladder was automatically segmented with our Conjoint Level set Analysis and Segmentation System (CLASS). In this preliminary study, we developed a system for detecting mass within the contrast-enhanced (C) region of the bladder. The C region was delineated from the segmented bladders using a method based on maximum intensity projection. The bladder wall of the C region was extracted using thresholding to remove the contrast material. The wall on each slice was transformed into a wall profile. Morphology and voxel intensity along the profile were analyzed and suspicious locations were labeled as lesion candidates. The candidates were automatically segmented using a modified AI-CALS segmentation method, and 27 morphological features were extracted. A data set of 70 patients with 98 biopsy-proven bladder lesions within the C region was used. The cases were split evenly into independent training and test sets: 35 training cases with 45 lesions, and 35 test cases with 53 lesions. Using the training set, stepwise feature selection with simplex optimization was used to select the best features. A linear discriminant (LDA) classifier was designed using the training set to merge the 6 selected features for classification of bladder lesions and false positives. The LDA classifier was then applied to the test set. CAD performance was evaluated by FROC analysis. At 2.5 FPs/case, the sensitivities were 84.4% and 81.1% for the training and test sets, respectively, while at 1.7 FPs/case, the sensitivities were 77.8% and 75.5%, respectively.

9414-62, Session 13

Automatic identification of IASLC-defined mediastinal lymph node stations on CT scans using multi-atlas organ segmentation

Joanne Hoffman, Jiamin Liu, Evrim B. Turkbey, Lauren Kim, Ronald M. Summers, National Institutes of Health (United States)

Station-labeling of mediastinal lymph nodes is typically performed to identify the location of enlarged nodes for cancer staging. Stations are usually assigned in clinical radiology practice manually by qualitative visual assessment on CT scans, which is time consuming and highly variable. We developed a method that automatically recognizes the lymph node stations in thoracic CT scans based on the anatomical organs in the mediastinum. The organs are automated identified with multi-atlas label fusion. Our method consists of mediastinal organs segmentation, station map generation, and lymph node station label assignment. We applied this system to CT scans of 86 patients with 350 mediastinal lymph nodes

measuring equal or greater than 10 mm. The accuracy of the method was 83% for correct station assignment of lymph nodes.

9414-63, Session 13

Ureter segmentation in CT urography (CTU) by COMPASS with multiscale Hessian enhancement

Duncan Fairbanks, Univ. of Michigan (United States); Lubomir M. Hadjiiski, Heang-Ping Chan, Chuan Zhou, Univ. of Michigan Health System (United States); Richard H. Cohen, Univ. of Michigan (United States); Elaine M. Caoili, Kenny H. Cha, Univ. of Michigan Health System (United States)

We are developing a computerized system for automated segmentation of ureters in CTU, referred to as COmbined Model-guided Path-finding Analysis and Segmentation System (COMPASS). Ureter segmentation is a critical component for computer-aided detection of ureter cancer. A challenge for ureter segmentation is the presence of regions not well opacified with intravenous contrast. COMPASS consists of three stages: (1) adaptive thresholding and region finding, (2) path-finding and propagation, and (3) edge profile extraction and feature analysis. In this study, we evaluated a new method in which CTU images were pre-processed with 3D multiscale Hessian filtering that enhances tubular structures. Our goal is to compare the performance of COMPASS with and without multiscale Hessian enhancement. With IRB approval, 79 cases with 124 ureters and 10 cases with 18 ureters were collected retrospectively from patient files as training and test sets, respectively. On average, the ureters spanned 289 CT slices (range: 115-405, median: 302). More than half of the ureters contained malignant or benign lesions and some had ureter wall thickening due to malignancy. The segmentation performance was quantitatively assessed as the percentage of length that was successfully tracked for each ureter. COMPASS alone segmented, on average, 99.16% and 98.74% of each ureter in the training and test sets, respectively. COMPASS with Hessian enhancement segmented, on average, 97.89% and 99.63% of each ureter in the training and test sets, respectively. Although the difference did not reach statistical significance in this small test set, Hessian-enhanced tracking shows promise for overcoming certain types of difficult cases.

9414-64, Session 13

Automated branching pattern report generation for laparoscopic surgery assistance

Masahiro Oda, Tetsuro Matsuzaki, Yuichiro Hayashi, Nagoya Univ. (Japan); Takayuki Kitasaka, Aichi Institute of Technology (Japan); Kazunari Misawa, Aichi Cancer Ctr. Research Institute (Japan); Kensaku Mori, Nagoya Univ. (Japan)

This paper presents a method for generating branching pattern reports of abdominal blood vessels for laparoscopic gastrectomy. In gastrectomy, it is very important to understand branching structure of abdominal arteries and veins, which are related to abdominal organs including the stomach, the liver and the pancreas. In the real clinical stage, a surgeon creates a diagnostic report of the patient anatomy. This report summarizes the branching patterns of the blood vessels related to the stomach. The surgeon decides actual operative procedure. This paper shows an automated method to generate a branching pattern report for abdominal blood vessels based on automated anatomical labeling. The report contains 3D rendering showing important blood vessels and descriptions of branching patters of each vessel. We have applied this method for fifty cases of 3D abdominal CT scans and confirmed the proposed method can automatically generate branching pattern reports of abdominal arteries.

9414-65, Session 13

Prediction of treatment outcome in soft tissue sarcoma based on radiologically defined habitats

Hamidreza Farhidzadeh, Baishali Chaudhury, Mu Zhou, Dmitry B. Goldgof, Lawrence O. Hall, Univ. of South Florida (United States); Robert A. Gatenby, Robert J. Gillies, Meera Raghavan, H. Lee Moffitt Cancer Ctr. & Research Institute (United States)

Soft tissue sarcomas are malignant tumors which develop from tissues like fat, muscle, nerves, fibrous tissue or blood vessels. They are challenging to physicians because of their relative infrequency and diverse outcomes, which has hindered development of new therapeutic agents. Additionally, assessing imaging response of these tumors to therapy is also difficult because of their heterogenous appearance on magnetic resonance imaging (MRI). In this paper, we assessed standard of care MRI sequences performed before and after treatment using 30 patients with soft tissue sarcoma. Tumor tissue was identified by manually drawing a mask on contrast enhanced images. The Otsu segmentation method was applied to segment tumor tissue into low and high signal intensity regions on both T1 post-contrast and T2 non-contrast images. This resulted in four distinctive subregions or "habitats." The features used to predict metastatic tumors and necrosis included the ratio of habitat size to whole tumor size and components of 2D intensity histograms. Individual cases were correctly classified as metastatic or non-metastatic disease with 93.33% accuracy based on 5 features and for necrosis ≥ 90 or necrosis < 90 with 74.04% accuracy based on 4 features by using meta-classifiers which contained feature selectors and classifiers.

9414-41, Session PS1

Potential reasons for discrepancies in CAD effectiveness between observer studies and clinical practice

Xin He, Frank W. Samuelson, Rongping Zeng, Berkman Sahiner, U.S. Food and Drug Administration (United States)

While laboratory reader studies often show the effectiveness of mammography computer aided diagnosis (CAD), this finding cannot be replicated in many clinical studies. Although this discrepancy may be attributable to many factors, it also prompts us to ask whether there are factors that affect the effectiveness of CAD in clinical practice but were not considered in laboratory reader studies. In a reader study for CAD assessment, surrogate laboratory reader data is analyzed to infer/predict the clinicians' performance improvement using CAD in clinical practice. The reader study data is surrogate because of the unavoidable differences between lab and practice. For example, the disease prevalence is around 50% in laboratory studies, which is 100 times higher than that in breast cancer screening. Although ROC is prevalence-independent, CAD involves tasks that are far more complicated than binary classification: search, detection, classification, cueing and learning. We have developed predictive/ derivative behavior models for these tasks. The models are validated or partially validated using various prediction studies. We apply these models to understand human/CAD interaction, which allows us to conjecture two factors that may contribute to the discrepancy of the CAD effectiveness: the prevalence effect on cue validity (co-occurrence of cue and signal) and the learning of cue validity. We hope this work will shed light on the need for the validation of task-based assessment methodologies to enable better prediction of clinical performance from reader studies. We also hope this work may lead to improvement of current CAD techniques by taking human behavior characteristics into the design consideration.

9414-66, Session PS1

Usefulness of histogram analysis of spatial frequency components for exploring the similarity and bilateral asymmetry in mammograms

Kenshi Shiotsuki, Yusuke Matsunobu, Hidetake Yabuuchi, Junji Morishita, Kyushu Univ. (Japan)

The left and right mammograms from the same patient are assumed to be bilaterally symmetric for image readings. The detection of asymmetry in bilateral mammograms is reliable indicator for detecting possible breast abnormalities. The purpose of this study was to examine the potential usefulness of a new method in terms of spatial frequency components for exploration of similarity and bilateral asymmetry between the left and right mammograms. A total of 98 normal and 119 abnormal cases with microcalcifications (MCC) were used for this study. Each case included two mediolateral oblique views. The spatial frequency components were determined from the symmetric regions in the left and right mammograms by Fourier transform. The degrees of conformity between the two spatial frequency components in the left and right mammograms were calculated for the same and different patients. The degree of conformity was also examined for cases with and without MCC for the same patient to show if the proposed method was useful for indicating the existence of MCC or not. The average degrees of conformity and standard deviations for the same and different patients were 0.911 ± 0.0165 and 0.857 ± 0.0328, respectively. The degrees of conformity calculated from abnormal cases (0.836 ± 0.0906) showed statistically lower values compared with those measures from normal cases (0.911 ± 0.0165). Our results indicated that histogram analysis of spatial frequency components could be useful as a similarity measure between the left and right mammograms for the same patient and abnormal signs in a mammogram.

9414-67, Session PS1

Lesion detection in dynamic contrast enhanced magnetic resonance imaging of breast

Xi Liang, Univ. of Melbourne (Australia); Romamohanarao Kotagiri, The Univ. of Melbourne (Australia); Helen Frazer, St Vincent's Hospital Melbourne Pty Ltd (Australia); Qing Yang, Apollo Medical Imaging Technology Pty Ltd. (Australia)

We propose an automated lesion detection method in dynamic contrast enhanced magnetic resonance imaging (DCE-MRI) of breast. There are three components: pre-processing to reduce motion using a nonrigid registration and extract breasts using a Hessian based method, threshold-based initial lesion detection and reduction of false positives using support vector machine.

In the initial lesion detection phase, we compute subtraction intensity, enhancement integral and early enhancement rate (EER) of each pixel in a DCE-MR image to represent kinetic information of the image. Since the kinetic features of the same tissue can vary significantly among patients, we normalize the features to percentile values. In the training set, the minimum percentile of each feature are defined as threshold. The thresholds are applied to the corresponding features in the testing cases to obtain three binary masks. Morphological closing is applied to the intersection of the three binary images to obtain the initial detection results.

In the false positive reduction phase, we extract 6 features in each region obtained in the initial identification phase. The kinetic features include the cumulative histogram of mean values of integral, EER and subtraction intensity of a region. We also compute the mean values of the regions in the resulting images processed by applying a vesselness and bulbness filter. The lesion volume is also a feature. Support vector machine is used to classify these regions into lesion and non-lesion.

We achieved 100% sensitivity in both initial and FP reduction phases and the FP number per lesion was reduced from 11 in the initial phase to 5.04 in the FP reduction phase.

9414-68, Session PS1

Fully automated quantitative analysis of breast cancer risk in DCE-MR images

Luan Jiang, Shanghai Advanced Research Institute (China); Xiaoxin Hu, Fudan Univ. (China); Yajia Gu, Fudan Univ. Shanghai Cancer Ctr. (China); Qiang Li, Shanghai Advanced Research Institute (China) and Shanghai United Imaging Healthcare Co., Ltd. (China)

Amount of fibroglandular tissue (FGT) and background parenchymal enhancement (BPE) in dynamic contrast enhanced magnetic resonance (DCE-MR) images are two important indices for breast cancer risk assessment in the clinical practice. The purpose of this study is to develop and evaluate a fully automated scheme for quantitative analysis of FGT and BPE in DCE-MR images. Our fully automated method consists of three steps, i.e., segmentation of whole breast, fibroglandular tissues, and enhanced fibroglandular tissues. Based on the volume of interest extracted automatically, dynamic programming method was applied in each 2-D slice of a 3-D MR scan to delineate the chest wall and breast skin line for segmenting the whole breast. This step took advantages of the continuity of chest wall and breast skin line across adjacent slices. We then further used fuzzy c-means clustering method with automatic selection of cluster number for segmenting the fibroglandular tissues within the segmented whole breast area. Finally, a statistical method was used to set a threshold based on the estimated noise level for segmenting the enhanced fibroglandular tissues in the subtraction image of pre- and post-contrast MR scans. Based on the segmented whole breast, fibroglandular tissues, and enhanced fibroglandular tissues, FGT and BPE were automatically computed. Preliminary results of technical evaluation and clinical validation showed that our fully automated scheme could obtain good segmentation of the whole breast, fibroglandular tissues, and enhanced fibroglandular tissues to achieve accurate assessment of FGT and BPE for quantitative analysis of breast cancer risk.

9414-69, Session PS1

Quantification of tumor changes during neoadjuvant chemotherapy with longitudinal breast DCE-MRI registration

Jia Wu, Univ. of Pennsylvania (United States); Yangming Ou, Massachusetts General Hospital (United States) and Harvard Univ. (United States); Susan P. Weinstein, Emily F. Conant, Ning Yu, Vahid Hoshmand, The Univ. of Pennsylvania Health System (United States); Brad M. Keller, Univ. of Pennsylvania School of Medicine (United States); Ahmed B. Ashraf, The Univ. of Pennsylvania Health System (United States); Mark A. Rosen, Hospital of the Univ. of Pennsylvania (United States); Angela DeMichele, Christos A. Davatzikos, Despina Kontos, The Univ. of Pennsylvania Health System (United States)

Imaging plays a central role in the evaluation of breast tumor response to neoadjuvant chemotherapy. Image-based assessment of tumor change via deformable registration is a powerful, quantitative method to potentially explore novel information of tumor heterogeneity, structure, function, and treatment response. In this study, we continued a previous pilot study to further validate the feasibility of an open source deformable registration algorithm DRAMMS developed within our group as a means to analyze spatio-temporal tumor changes for a set of 14 patients with DCE-MR

imaging. Two experienced breast imaging radiologists marked landmarks according to their anatomical meaning on image sets acquired before and after chemotherapy. Yet, chemotherapy remarkably changed the anatomical structure of both tumor and normal breast tissue, leading to significant discrepancies between both raters for landmarks in certain areas. Therefore, we proposed a novel method to grade the manually denoted landmarks into different levels based on the variation between two raters, where a high level indicates large discrepancies and considerable anatomical structure changes, which would certainly impose giant challenge for the registration algorithm. It is interesting to observe that DRAMMS performed in a similar manner to human raters: landmark errors increased as differences between the two raters rose. Among all selected six deformable registration algorithms, DRAMMS achieves the highest overall accuracy, which is around 5.5 mm, while the average difference between human raters is 3 mm. Additionally, DRAMMS performed consistently well within both tumor and normal tissue regions. On the other hand, we comprehensively tuned the fundamental parameters of DRAMMS to further optimize the registration results. Overall, we further proved that DRAMMS is a powerful registration tool to accurately quantify tumor changes and potentially predict early tumor response to chemotherapy. Future studies could examine if DRAMMS can generate valuable biomarkers for tumor response prediction during chemotherapy.

9414-70, Session PS1

A new Fourier transform based CBIR scheme for mammographic mass classification: a preliminary invariance assessment

Rohith Reddy Gundreddy, Maxine Tan, Yuchen Qui, Bin Zheng, The Univ. of Oklahoma (United States)

Content-based image retrieval (CBIR) has been widely investigated and tested in developing computer-aided detection or diagnosis (CAD) schemes and in particular in interactive CAD schemes. The CBIR algorithms used in CAD are typically based on either pre-defined image features computed from the segmented lesions or regional based image pixel value distribution without lesion segmentation. Both have advantages and limitations. Recently, we investigated and tested a new Fourier transform based CBIR algorithm that determines the image similarity based on regional image pixel value distribution in the Fourier transform mapped image. Since Fourier transform of each reference image can be pre-computed and the image feature inconsistency can be avoided without lesion segmentation, the new algorithm takes advantages of both high computational efficiency and feature accuracy of two types of previous CBIR algorithms. However, one important issue that has not been well investigated is how the CBIR algorithm is robust to the lesion position shift, rotation, and size change (or zooming affect), which is particular important for the CBIR algorithm using the regional image feature similarity. To investigate this issue, we in this study tested and examined the selected similar reference images and their similarity scores to the queried image as functions of the lesion center shift and zooming ratios of the queried lesion. Our preliminary test results showed that the retrieved reference images by the Fourier transform based similarity scores was highly invariant to the queried lesion position shift (e.g., up to one tenth of image region) and size zooming (e.g., <25%).

9414-71, Session PS1

Utilizing digital breast tomosynthesis projection views correlation for microcalcification enhancement for detection purposes

Wissam J. Baddar, Eun Joon Kim, Dae Hoe Kim, Yong Man Ro, KAIST (Korea, Republic of)

This paper presents a novel method for enhancing the contrast of microcalcifications in digital breast tomosynthesis projection views for detection purposes. The proposed method relies on the correlation between the projection views in order to reduce the effect of the noise, due to the low-dose exposure, and increase the contrast of the microcalcification particles for microcalcification cluster detection purposes. The method performs a series of multi-shift operations to capture the microcalcification particle movement information and compensate it in order to enhance microcalcification particles contrast. Furthermore, the proposed approach utilizes the projection view correlation in order to reduce the falsely detected regions of interest, and improve the classification of the detected regions into false positives or actual microcalcification clusters. Comparative and extensive experiments have been performed to quantitatively measure the contrast enhancement of microcalcification particles and its effect on the MC cluster detection. To that end, the contrast to noise ratio have been calculated and compared with some with previous methods. Furthermore, the free response receiver operating characteristic (FROC) curve have been used to measure the effect of the proposed enhancement on the microcalcification cluster detectability.

9414-72, Session PS1

A new breast cancer risk analysis approach using features extracted from multiple sub-regions on bilateral mammograms

Wenqing Sun, Tzu-Liang B. Tseng, The Univ. of Texas at El Paso (United States); Bin Zheng, The Univ. of Oklahoma (United States); Jianying Zhang, The Univ. of Texas at El Paso, United States (United States); Wei Qian, The Univ. of Texas at El Paso (United States)

A novel breast cancer risk analysis approach is proposed for enhancing performance of computerized breast cancer risk analysis using bilateral mammograms. Based on the intensity of breast area, five different sub-regions were acquired from one mammogram, and bilateral features were extracted from every sub-region. Our dataset includes 180 bilateral mammograms from 180 women who underwent routine screening examinations, all interpreted as negative and not recalled by the radiologists during the original screening procedures. A computerized breast cancer risk analysis scheme using four image processing modules, including sub-region segmentation, bilateral feature extraction, feature selection, and classification was designed to detect and compute image feature asymmetry between the left and right breasts imaged on the mammograms. The highest computed area under the curve (AUC) is 0.763 ± 0.021 when applying the multiple sub-region features to our testing dataset. The positive predictive value and the negative predictive value are 0.60 and 0.73, respectively. The study demonstrates that (1) features extracted from multiple sub-regions can improve the performance of our scheme compared to using features from whole breast area only; (2) a classifier using asymmetry bilateral features can effectively predict breast cancer risk; (3) incorporating texture and morphological features with density features can boost the classification accuracy.

9414-73, Session PS1

Chest wall segmentation in automated 3D breast ultrasound using rib shadow enhancement and multi-plane cumulative probability enhanced map

Hyunjin Kim, Hannah Kim, Helen Hong, Seoul Women's Univ. (Korea, Republic of)

In 3D ABUS images, determining the location of chest wall is necessary to reduce false positives of CAD systems by detecting tumors and glandular tissues beyond the chest wall. Moreover, it serves as an effective boundary to register a 3D breast ultrasound image to other images acquired by different modalities. However, any chest wall is not visible due to speckle noise and the identification between chest wall and glandular tissue is difficult due to their similar intensity. Thus, we propose an automatic segmentation method of chest wall in 3D ABUS images using rib shadow enhancement and multi-plane cumulative probability enhanced map. First, to identify individual rib shadows, contrast between rib shadow and intercostal region is enhanced using intensity transfer function. Then, rib shadow with sheet-like structure is enhanced using 3D sheet-like enhancement filtering based on the Hessian matrix. Second, to separate rib shadow from intercostal region, probability enhanced map is cumulated in the coronal direction at the bottom of sagittal plane and wrongly enhanced regions with low probability are removed. Third, to remove the small fatty tissues at the top of rib shadow, probability enhanced map is cumulated in the sagittal direction at some slices of sagittal plane and wrongly enhanced regions with low probability are removed. Then, the large fatty tissues with globular and sheet-like shapes at the top of rib shadow are removed using shape and orientation analysis based on moment matrix. Finally, detected chest walls are connected with cubic B-spline interpolation. Experimental results show that the Dice similarity coefficient of proposed method as comparison with two manually outlining results provides over 90% in average.

9414-74, Session PS1

A new CAD approach for improving efficacy of cancer screening

Bin Zheng, The Univ. of Oklahoma (United States); Wei Qian, The Univ. of Texas at El Paso (United States); Lihua Li, Hangzhou Dianzi Univ. (China); Jiantao Pu, Univ. of Pittsburgh (United States); Yan Kang, Northeastern Univ. (China); Fleming Yuan Ming Lure, The Univ. of Texas at El Paso (United States); Maxine Tan, Yuchen Qiu, The Univ. of Oklahoma (United States)

Efficacy of current population-based cancer screening is a very controversial issue due to the high false-positive recall rates. Using conventional computer-aided detection (CAD) schemes also substantially increases false-positive recalls as demonstrated in many previous studies. In order to better address this difficult issue, we recently investigated a new CAD research direction aiming to assist improving efficacy of cancer screening using a number of new approaches. In this presentation we review our 5 recent publications in 2014 and summarize the new approaches and experimental results applying to breast cancer screening using either FFDM or DCE-MRI examination modalities. Unlike the previous lesion-based CAD schemes that primarily focused on detecting more positive lesions that may be missed or overlooked by radiologists with substantially higher false-positive detections, we used lesion-free and multi-image based CAD approaches that only focus on the detection and analysis of global image features to predict near-term cancer development risk and/or classify between the true- and false-positive recalls (or cases). For example, (1) using a scheme to analyze bilateral mammographic tissue density asymmetry, the computed odds ratios showed an increasing risk trend from 1.00 to 9.07 between positive and negative case groups. (2) Analyzing the global MR kinetic image features, a CAD scheme achieved an area under ROC curve of AUC=0.839. (3) Combing the global image features from four-view FFDM images, CAD yielded AUC=0.793 in classifying 1052 recalled cases. These preliminary studies demonstrated a new CAD research direction and its feasibility to potentially help establish more effective personalized cancer screening paradigm and/or reduce the false-positive recalls.

9414-75, Session PS1

Feature extraction from inter-view similarity of DBT projection views

Dae Hoe Kim, Seong Tae Kim, Yong Man Ro, KAIST (Korea, Republic of)

In this paper, new features based on inter-view similarity are proposed for classifying masses, aiming to effectively reducing false-positives (FPs). The proposed features are focused on utilizing inter-view information in projection views. The FPs induced by overlapping tissues of different depth could be observed differently between projection views, while masses could appear similarly. To utilize the observation, the inter-view similarity measure is developed by utilizing the normalized cross-correlation. On the analysis of inter-view similarities of masses and FPs, it is showed that inter-view similarities of FPs are lower than those of masses. To that end, new features are proposed to encode aforementioned difference of inter-view similarities between FPs and masses. Experimental results show that the proposed features can improve the mass classification performance in projection views in terms of the area under the ROC curve.

9414-77, Session PS1

Simplified false-positive reduction scheme in computer-aided detection of clustered microcalcifications in digital breast tomosynthesis

Ji-Wook Jeong, Seung-Hoon Chae, Sooyeul Lee, Electronics and Telecommunications Research Institute (Korea, Republic of); Eun Young Chae, Hak Hee Kim, Asan Medical Ctr. (Korea, Republic of); Young-Wook Choi, Korea Electrotechnology Research Institute (Korea, Republic of)

Digital breast tomosynthesis (DBT) has been considered as a promising image modality for detection and diagnosis of microcalcifications (MCs) in breast. Computer-aided detection (CADe) may play an important role in MC detection in DBT than in mammography by automatically searching for MC clusters (MCCs) in a 3D DBT image volume within a relatively short time. In this paper, we tried to suggest the simple and efficient false-positive (FP) reduction scheme coupled with the detection algorithm of MCCs in the DBT volume using 3D objectness-enhanced and signal-to-noise-ratio-enhanced images. The system consisted of prescreening, MC detecting, clustering, and FP reduction steps. In the prescreening stage, the MC-like objects were enhanced by a multiscale-based 3D calcification response function. A connected component segmentation method was used to detect cluster seed objects, considered as potential clustering centers of MCs. Starting with each cluster seed object as the initial cluster center, a cluster candidate was formed by including nearby MC candidates within a 3D neighborhood of the cluster seed object satisfying the clustering criteria during the clustering step. A bounding cube for each MCC was generated for each accepted seed candidates. Then, the overlapping cubes were combined and examined according to the pre-defined criteria. On a data set of two-view DBTs of 69 breasts with or without MCCs, a sensitivity of 83.3% was achieved at 2.47 FPs per volume. Our study indicates the simplified FP reduction approach applied to the detection of clustered MCs in DBT is promising as an efficient CADe system.

9414-78, Session PS1

Assessing the combined performance of fractal dimension and entropy parameters in distinguishing breast tumors in acoustic radiation force impulse (ARFI) imaging

Hsiao-Chuan Liu, Univ. of California, San Francisco (United States); Yi-Hong Chou, Taipei Veterans General Hospital (Taiwan) and National Yang Ming Univ. (Taiwan); Chui-Mei Tiu, Taipei Veterans General Hospital (Taiwan) and National Yang Ming Univ. (Taiwan) and Ching Chyuan Hospital (Taiwan); Chi-Wen Hsieh, National Chiayi Univ. (Taiwan); Tai-Lang Jong, National Tsing Hua Univ. (Taiwan)

Acoustic radiation force impulse (ARFI) imaging is widely utilized to evaluate the tissue stiffness by using short-duration acoustic pulses to generate small localized tissue displacements. The tissue stiffness is illustrated as qualitative grayscale map by virtual touch imaging (VTI) technique. The fractal dimension and entropy parameter were proposed to evaluate the texture of VTI to differentiate malignant from benign breast lesions. Thirty eight ARFI with VTI were retrospected. Region of interests (ROI) was drawn manually on conventional ultrasound image, and then the boundary of ROIs was mapped to VTI in the same space. The texture of VTI was analyzed by using fractal dimension and entropy parameter. Significant difference in values between malignant and benign lesions were examined by using an independent samples t test. Linear discriminant analysis (LDA) was utilized to classify the malignant from benign breast lesions. Sensitivity, specificity and accuracy were calculated. The area under the curve (AUC) were obtained by using a receiver operating characteristic (ROC) curve analysis to assess diagnostic performance. Both features, entropy and combined two fractal features, for malignant lesions differed significantly from that for benign lesions ($p < 0.001$). The AUC of combined two fractal features, entropy and all features presented 0.942, 0.994 and 1, respectively. For considering all features, the sensitivity, specificity and accuracy reach to 100%, 83.3%, 92% (cross-validated), respectively. The texture of ARFI with VTI was successfully distinguished malignant from benign breast lesions by using fractal analysis and entropy parameter.

9414-79, Session PS1

Automatic breast density classification using a convolutional neural network architecture search procedure

Pablo Fonseca, Julio Mendoza, Jacques Wainer, Univ. Estadual de Campinas (Brazil); Jose Ferrer, Pontificia Univ. Católica del Perú (Peru); Joseph A. Pinto, Jorge Guerrero, Oncosalud (Peru); Benjamin Castañeda, Pontificia Univ. Católica del Perú (Peru)

Breast parenchymal density is considered a strong indicator of breast cancer risk and therefore a useful indicator for preventive tasks. Measurement of breast density is often qualitative and requires the subjective judgment of radiologists. Here we explore automatic breast composition classification based on convolutional neural networks in combination with a support vector machines classifier. This is compared to the assessments of seven experienced radiologists. The experiments yielded an average kappa value of 0.58 when using the mode of the radiologist's classifications as ground truth. Individual radiologist performance against this ground truth yielded kappas between 0.56 and 0.79.

9414-80, Session PS1

Automated detection of breast tumor in MRI and comparison of kinetic features for assessing tumor response to chemotherapy

Faranak Aghaei, Maxine Tan, Bin Zheng, The Univ. of Oklahoma (United States)

Dynamic contrast-enhanced breast magnetic resonance imaging (DCE-MRI) has been used increasingly in breast cancer diagnosis and assessment of cancer treatment efficacy. In order to better predict breast cancer prognosis using MR images, we in this study developed and applied a CAD scheme to automatically segment breast regions depicted on MR images, detect breast tumor locations, segment breast tumor volumes and also delete the fat or necrotic volumes inside the tumors. We then computed tumor kinetic features as well as the effective tumor volume with contrast enhancement. The objective of this study is to compare feature difference of the MRI-depicted breast tumors and investigate the feasibility of using these features

to predict tumor response to the chemotherapy. CAD scheme was applied to breast MR images of 26 patients. Each has two sets of pre- and post-chemotherapy examinations. CAD results indicated that 20 patients had "complete response" (CR) to chemotherapy because the enhanced contrast levels inside the tumor volume (pre-treatment) was reduced to the level as the normal enhanced background parenchymal tissues (post-treatment) and 6 had "partially response" (PR) in which the high contrast enhancement remain in the tumor regions after treatment. The data analysis results also showed the different kinetic feature difference between these two groups of patients. For example, the tumors with high ratio of necrotic (low-enhanced) volume ratio tend to have favorable response to the treatment. The study indicates a new potential of applying CAD of breast MR images to detect and/or predict patients' prognosis or response to chemotherapy.

9414-81, Session PS1

Preliminary study on the automated detection of breast tumors using the characteristic features from unenhanced MR images

Hayato Adachi, Atsushi Teramoto, Fujita Health Univ. (Japan); Satomi Miyajo, Osamu Yamamuro, Kumiko Ohmi, East Nagoya Imaging Diagnosis Ctr. (Japan); Masami Nishio, Nagoya Radiological Diagnosis Ctr. (Japan); Hiroshi Fujita, Gifu Univ. (Japan)

Breast cancer incidence tends to rise globally and the mortality rate for breast cancer is increasing in Japan. There are various screening modalities for breast cancer, and MRI examinations with high detection rate are used for high-risk groups, which are genetically prone to develop breast cancer. However, these examinations require contrast agents for dynamic imaging and may harm the screening examinees. MRI provides the anatomical and functional information by using various sequences. According to the reports, this information can discriminate between tumor and normal tissue. In this study, we analyzed unenhanced MR images by using plural sequences and developed an automated method for the detection of tumors. First, we extracted the breast region from the T1-weighted image semi-automatically. Next, using the threshold determined by considering the signal intensities of tumor and normal tissue, a thresholding method was applied to extract the first candidate regions. After labeling processing, the characteristic features obtained from the T1-weighted image, the T2-weighted image, and the diffusion-weighted image were input to an artificial neural network, which could distinguish their true positive from their false positives. Finally, we examined the remaining candidates as possible tumor regions. We applied the proposed method to 14 cases of MR images and evaluated its usefulness. As a result, the detection sensitivity was 71% and the abnormal regions were clearly detected. These results indicate that the proposed method may be useful for tumor detection in unenhanced breast MR images.

9414-82, Session PS1

Estimation of corresponding locations in ipsilateral mammograms: a comparison of different methods

Matthias Wilms, Julia Krüger, Mirko Marx, Jan Ehrhardt, Univ. zu Lübeck (Germany); Arpad Bischof, Universitätklinikum Schleswig-Holstein (Germany); Heinz Handels, Univ. zu Lübeck (Germany)

Mammography is a standard tool for breast cancer diagnosis. In current clinical practice, typically two mammograms of each breast are taken from different angles. A fundamental step when using ipsilateral mammograms for the diagnosis of breast cancer, is the identification of corresponding locations/structures in both views, which is a very challenging task due to the projective nature of the images and the different compression

parameters used for each view. In this contribution, four different approaches for the estimation of corresponding locations in ipsilateral mammograms are systematically compared using 10 mammogram pairs. The evaluation includes simple heuristic methods (annular bands and straight strips) as well as methods based on geometric and physically motivated breast compression models, which aim to simulate the mammogram acquisition process. The evaluation results show that on average no significant differences exist between the estimation accuracies obtained using the simple heuristic methods and the more involved compression models. However, the results of this study indicate the potential of a method that optimally combines the different approaches.

9414-83, Session PS1

Hybrid unsupervised-supervised lesion detection in mammograms

Aviad Zlotnick, IBM Research - Haifa (Israel); Boaz Ophir, IBM Research - Hafia (Israel); Pavel Kisilev, IBM Research - Haifa (Israel)

Automatic lesion detection is believed to be one of the most challenging and still open problems in breast imaging, and in particular, in mammography. The main difficulty stems from the fact that various objects' and tissues' appearance in mammogram is similar to the one of a lesion. This results in high false- and miss-detection rates at the same time.

In this paper we propose a novel approach that combines unsupervised and supervised steps. In the first, unsupervised step, we produce a relatively large number of possible lesion candidates. This stage is based on the semantic threshold binarization approach to find initial seeds. Given the seeds, we use dynamic programming framework and analyze local gradients to expand each of the seeds to obtain candidate contours. This unsupervised step yields up to 100 possible contour candidates. In the second, supervised step, we calculate a set of rich features for each contour candidate, and train a RankSVM-type classifier to select the best candidate based on these features. In the experiments on a set of nearly 200 mammogram images we show that the proposed method shows very promising results.

9414-84, Session PS2

3D active shape models of human brain structures: Application to patient-specific mesh generation

Nishant Ravikumar, Isaac Castro, José M. Pozo, Alejandro F. Frangi, Zeike A. Taylor, The Univ. of Sheffield (United Kingdom)

Statistical models of shape and appearance are important tools for medical image analysis and segmentation. This study explores construction of statistical models of shape (i.e. SSM as a point distribution model or PDM), & grey-level appearance (SGAM), of the brain, towards development of a mesh generation pipeline for personalised computational modelling. The brain structures of interest are - the cortical surface (cerebrum, cerebellum & brainstem), lateral ventricles & falx membrane. Two methods for establishing correspondences across training shapes are investigated and compared: the Coherent Point Drift (CPD) point-set registration method and B-Spline mesh-to-mesh registration method. Both methods are geared towards deformably aligning shapes with unequal number of points/vertices. The MNI 305 average brain atlas is used to generate the template mesh which is deformably registered to each training case, to establish correspondence across the set of training shapes. 20 healthy patients' T1-weighted MR images are used to generate & assemble meshes of the structures of interest and are subsequently used to train the SSM & SGAM. Both training and model-fitting (to new patient images) are performed over multiple brain structures simultaneously. The compactness of the PDMs and the quality of the SSMs generated using both registration techniques are compared using

the 'leave-one-out' cross validation method. The mesh-based SSM is found to produce better results.

9414-85, Session PS2

Computer-aided recognition of dental implants in X-ray images

Pedro Morais, ICVS/3B's - PT Government Associate Lab., Univ do Minho (Portugal); Sandro Queirós, ICVS/3B's - PT Government Associate Lab. (Portugal) and Univ. do Minho (Portugal); António H. Moreira, ICVS/3B's - PT Government Associate Lab. (Portugal) and Univ. of Minho (Portugal) and DIGARC – Polytechnic Institute of Cávado and Ave (Portugal); Adriano Ferreira, Life and Health Sciences Research Institute (Portugal); Ernesto Ferreira, DIGARC – Polytechnic Institute of Cávado and Ave (Portugal); Duarte Duque, DIGARC, Instituto Politécnico do Cávado e do Ave (Portugal); Nuno F. Rodrigues, ICVS/3B's - PT Government Associate Lab. (Portugal) and Univ. do Minho (Portugal) and DIGARC, Instituto Politécnico do Cávado e do Ave (Portugal); João L. Vilaça, ICVS/3B's - PT Government Associate Lab. (Portugal) and DIGARC, Instituto Politécnico do Cávado e do Ave (Portugal)

Background: Dental implant recognition in patients without available records is a time-consuming and not straightforward task. The traditional method is a complete user-dependent process, where the expert compares a bidimensional X-ray of the dental implant with a generic database. Due the high number of implants available and the similarity between them, automatic/semi-automatic frameworks to aide implant model detection are essential.

Methods: A novel computer-aided framework for dental implant recognition is suggested. The proposed method relies on image processing concepts, namely: (i) a segmentation strategy for semi-automatic implant delineation; and (ii) a machine learning approach for implant model recognition. Although the segmentation technique is the main focus of the current study, preliminary details of the machine learning approach are also reported.

Results: Two different scenarios are used to validate the framework: (1) comparison of the semi-automatic contours against manual implant delineation of 125 X-ray images; and (2) classification of 11 known implants using a large reference database of 601 implants. Regarding experiment 1, 0.97±0.01, 2.24±0.85 pixels and 11.12±6 pixels of dice metric, mean average distance and Hausdorff distance were obtained, respectively. In experiment 2, 91% of the implants were successfully recognized while reducing the reference database to 5% of its original size.

Conclusions: The segmentation technique achieved accurate implant contours. Although the preliminary classification results prove the concept of the current work, more features and an extended database should be used in a future work.

9414-87, Session PS2

Computer aided detection of brain micro-bleeds in traumatic brain injury

Thomas van den Heuvel, Technische Univ. Eindhoven (Netherlands); Mohsen Ghafoorian, Radboud Univ. Nijmegen (Netherlands); Anke W. van der Eerden, Radboud Univ. Nijmegen Medical Ctr. (Netherlands); Bozena M. Goraj, Radboud Univ. Nijmegen Medical Ctr. (Netherlands) and Medical Ctr. of Postgraduate Education (Poland); Teuntje M. J. C. Andriessen, Radboud Univ. Medical Ctr. (Netherlands); Bart M. ter Haar Romeny, Technische Univ. Eindhoven (Netherlands); Bram Platel, Radboud Univ. Medical Ctr. (Netherlands)

Brain micro-bleeds (BMBs) are used as surrogate markers for detecting diffuse axonal injury in Traumatic Brain Injury (TBI) patients. The location and number of BMBs have been shown to influence the long-term outcome of TBI. To further study the importance of BMBs for prognosis, accurate localization and quantification are required. The task of annotating BMBs is laborious, complex and prone to error and inter- and intra-reader variability. In this paper we propose a Computer Aided Detection (CAD) system to automatically detect BMBs in MRI scans of moderate to severe neuro-trauma patients. Our method consists of four steps. Step one: preprocessing of the data. Both susceptibility (SWI) and T1 weighted MRI scans are used. The images are co-registered, a brain-mask is generated, the bias field is corrected, and the image intensities are normalized. Step two: initial candidates for BMBs are selected as local minima in the processed SWI images. Step three: feature extraction. BMBs appear as a round or ovoid signal hypo-intensities on SWI. Thirteen features are computed to capture these properties of a BMB. Step four: Classification. To identify BMBs from the set of local minima using their features, different classifiers are trained on a database of 33 expert annotated scans and 18 healthy subjects with no BMBs. Our system uses a leave-one-out strategy to analyze performance. With a sensitivity of 90% with 1.3 false positives per BMB our CAD system shows superior results compared to state-of-the-art BMB detection algorithms (developed for non-trauma patients).

9414-88, Session PS2

Automatic segmentation method of striatum regions in quantitative susceptibility mapping images

Saki Murakawa, Yoshikazu Uchiyama, Toshinori Hirai, Kumamoto Univ. (Japan)

Abnormal accumulation of brain iron has been detected in various neurodegenerative diseases. Quantitative susceptibility mapping (QSM) is a novel contrast mechanism in magnetic resonance (MR) imaging and enable the quantitative analysis of local tissue susceptibility property. Therefore, automatic segmentation tools of brain regions on QSM images would be helpful for radiologists' quantitative analysis in various neurodegenerative diseases. The purpose of this study was to develop an automatic segmentation and classification method of striatum regions on QSM images. Our image database consisted of 22 QSM images obtained from healthy volunteers. These images were acquired on a 3.0 T MR scanner. The voxel size is 0.9?0.9?2 mm. The matrix size of each slice image was 256?256 pixels. In our computerized method, a template mating technique was first used for the detection of a slice image with striatum regions. An image registration technique was subsequently employed for the classification of striatum regions in consideration of the anatomical knowledge. After the image registration, the voxels in the target image which correspond with striatum regions in the reference image were classified into three striatum regions, head of the caudate nucleus, putamen, and globus pallidus. The experimental results indicated that 100% (21/21) of the slice images with striatum regions were accurately detected. The subjective evaluation of classification results indicated that 20 (95.2%) of 21 showed good or adequate quality. Our computerized method would be useful for the quantitative analysis of neurodegenerative diseases on QSM images.

9414-89, Session PS2

Decoding brain cancer dynamics: a quantitative histogram-based approach using temporal MRI

Mu Zhou, Lawrence O. Hall, Dmitry B. Goldgof, Univ. of South Florida (United States); Robert J. Gillies, Robert A.

Gatenby, H. Lee Moffitt Cancer Ctr. & Research Institute (United States)

Brain tumor heterogeneity remains a challenge for probing brain cancer evolutionary dynamics. In light of evolution, it is a priority to inspect the cancer system from a time-domain perspective since it explicitly tracks the dynamics of cancer variations. In this paper, we study the problem of exploring brain tumor heterogeneity from temporal clinical magnetic resonance imaging (MRI) data. Our goal is to discover evidence-based knowledge from such temporal imaging data, where multiple clinical MRI scans from Glioblastoma multiforme (GBM) patients are generated during therapy. In particular, we propose a quantitative histogram-based approach that builds a prediction model to measure the difference in histograms obtained from pre- and post-treatment. The study could significantly assist radiologists by providing a metric to identify distinctive patterns within each tumor, which is crucial for the goal of providing patient-specific treatments. We examine the proposed approach for a practical application---clinical survival group prediction. Experimental results show that our approach achieved 90.91% accuracy.

9414-90, Session PS2

Discriminative analysis of non-linear brain connectivity for leukoaraiosis

Youzhi Lai, Lele Xu, Li Yao, Xia Wu, Beijing Normal Univ. (China)

Leukoaraiosis (LA), which describes diffuse white matter abnormalities on CT or MR brain scans, can often be seen in the normal elderly and associated with vascular risk factors such as hypertension, or in the context of cognitive impairment. The mechanism of cognitive dysfunction in LA is still unclear. In recent years, resting-state functional connectivity analyses of LA have attracted considerable attention. However, the current functional connectivity analyses of LA have been mostly limited to linear associations. In this investigation, we applied a novel measure utilizing the extended maximal information coefficient (eMIC) to construct non-linear functional connectivity in 44 LA subjects (9 vascular dementia (VD), 25 mild cognitive impairment (MCI) and 10 normal controls (NC)). The functional network analysis revealed that the changes of the non-linear and linear connectivity had similar but not completely the same spatial distribution in human brain. In the classification analysis with multiple classifiers, the non-linear functional connectivity mostly classified VD, MCI and NC in LA with a relatively higher accuracy rate than the linear measure. Our findings revealed that the non-linear functional connectivity could provide useful discriminative power in the classification of LA, providing a new method to investigate the mechanism of cognitive dysfunction in LA.

9414-91, Session PS2

Automated classification of mandibular cortical bone on dental panoramic radiographs for early detection of osteoporosis

Kazuki Horiba, Chisako Muramastu, Gifu Univ. (Japan); Tatsuro Hayashi, Media Co,. Ltd. (Japan); Tatsumasa Fukui, Asahi Univ. (Japan); Takeshi Hara, Gifu Univ. (Japan); Akitoshi Katsumata, Asahi Univ. (Japan); Hiroshi Fujita, Gifu Univ. (Japan)

Findings on dental panoramic radiographs (DPRs) have shown that mandibular cortical index (MCI) based on the morphology of mandibular inferior cortex was significantly correlated with osteoporosis. MCI on DPRs can be categorized into one of three groups and has the high potential for identifying patients with osteoporosis. However, most DPRs are used for only diagnosing dental conditions by dentists in their routine clinical work. Moreover, MCI is not generally quantified but assessed subjectively.

In this study, we investigated a computer-aided diagnosis (CAD) system that automatically classifies mandibular cortical bone for detection of osteoporotic patients at early stage. First, an inferior border of mandibular bone was detected by use of an active contour method. Second, regions of interest including the cortical bone are extracted and analyzed for its thickness and roughness. Finally, support vector machine (SVM) differentiate cases into three MCI categories by features including the thickness and roughness. Ninety eight DPRs were used to evaluate our proposed scheme. The number of cases classified to Class I, II, and III by a dental radiologist are 55, 25 and 17 cases, respectively. Experimental result based on the leave-one-out cross-validation evaluation showed that the sensitivities for the classes I, II, and III were 91.0%, 60.0% and 100.0%, respectively. Distribution of the groups in the feature space indicates a possibility of MCI quantification by the proposed method. Therefore, our scheme has a potential in identifying osteoporotic patients at an early stage.

9414-92, Session PS2

Imbalanced learning for clinical survival group prediction of brain tumor patients

Mu Zhou, Lawrence O. Hall, Dmitry B. Goldgof, Univ. of South Florida (United States); Robert J. Gillies, Robert A. Gatenby, H. Lee Moffitt Cancer Ctr. & Research Institute (United States)

Accurate computer-aided prediction of survival time for brain tumor patients requires a thorough understanding of clinical data, since it provides useful prior knowledge for learning models. However, to simplify the learning process, traditional settings often assume datasets with equally distributed classes, which clearly does not reflect a typical underlying distribution. In this paper, we investigate the problem of mining knowledge from an imbalanced dataset (i.e., a skewed distribution) to predict survival time. In particular, we propose an algorithmic framework to predict survival groups of brain tumor patients using multi-modality MRI data. Both an imbalanced distribution and classifier design are jointly considered: 1) We used the Synthetic Minority Over-sampling Technique to compensate for the imbalanced distribution; 2) A predictive linear regression model was adopted to learn a pair of class-specific dictionaries, which were derived from reformulated balanced data. We tested the proposed framework using a dataset of 42 patients with Glioblastoma Multiforme (GBM) tumors whose scans were obtained from the cancer genome atlas (TCGA). Experimental results showed that the proposed method achieved 95.24% accuracy.

9414-93, Session PS2

Longitudinal MRI assessment: the identification of relevant features in the development of Posterior Fossa Syndrome in children

Michaela Spiteri, Emma Lewis, David Windridge, Univ. of Surrey (United Kingdom); Shivaram Avula, Alder Hey Children's NHS Foundation Trust (United Kingdom)

Up to 25% of children who undergo brain tumour resection surgery in the posterior fossa develop posterior fossa syndrome (PFS). This syndrome is characterised by mutism and disturbance in speech. Our hypothesis is that there is a correlation between PFS and the occurrence of hypertrophic olivary degeneration (HOD) in lobes within the posterior fossa, known as the inferior olivary nuclei (ION). HOD is exhibited as an increase in size and intensity of the ION on an MR image.

Intra-operative MRI (IoMRI) is currently being carried out during surgical procedures at the Alder Hey Children's Hospital, Liverpool, England, in the treatment of such tumours. The final MR scan on the IoMRI allows early assessment of the ION immediately after the surgical procedure.

The longitudinal MRI data of 28 patients was analysed in a collaborative

study with Alder Hey Children's Hospital, Liverpool, England, in order to identify the most relevant imaging features that relate to the development of PFS, specifically related to HOD.

A semi-automated segmentation process was carried out to delineate the ION on each MRI. Feature selection techniques were used to identify the most relevant features amongst the MRI data, demographics and clinical data provided by the hospital. A support vector machine (SVM) was used to analyse the integrity of the selected features. The results indicate the presence of HOD as the most efficient feature that correlates with the development of PFS, followed by the change in intensity and size of the ION and whether HOD occurred bilaterally or unilaterally.

9414-94, Session PS2

Quantification of vocal fold motion using echography: application to recurrent nerve paralysis detection

Mike-Ely Cohen, SATT Lutech (France); Muriel Lefort, INSERM (France) and Univ. Pierre et Marie Curie (France) and Ctr. National de la Recherche Scientifique (France); Heloise Bergeret-Cassagne, Assistance Publique – Hôpitaux de Paris (France); Siham Hachi, Univ. du Luxembourg (Luxembourg); Ang Li, INSERM (France) and UPMC Sorbonne Univ. (France) and Ctr. National de la Recherche Scientifique (France); Gilles Russ, Assistance Publique Hôpitaux de Paris (France); Diane Lazard, Assistance Publicque Hôpitaux de Paris (France); Fabrice Ménégaux, Assistance Publicque Hôpitaux de Paris (France) and UPMC Sorbonne Univ. (France) and UPMC Paris 6 (France); Laurence Leenhardt, Assistance Publique Hôpitaux de Paris (France) and UPMC Sorbonne Univ. (France) and UPMC Paris 6 (France); Christophe Tresallet, Assistance Publique Hôpitaux de Paris (France) and UPMC Sorbonne Univ. (France) and UPMC Paris 06 (France); Frederique Frouin, INSERM (France) and UPMC Sorbonne Univ. (France) and CNRS (France)

Recurrent nerve paralysis (RP) is one of the most frequent complications of thyroid surgery. It reduces vocal fold mobility. Nasal endoscopy, a mini-invasive procedure, is the conventional way to detect RP. We suggest a new approach based on laryngeal ultrasound and a specific data analysis was designed to help with the automated detection of RP.

Ten subjects were enrolled for this feasibility study: four controls, three patients with RP and three patients without RP according to nasal endoscopy. The ultrasound protocol was based on a ten seconds B-mode acquisition in a coronal plane during normal breathing. Image processing included three steps: 1) detection of two consecutive closing and opening images, corresponding to extreme positions of vocal folds in the sequence of B-mode images, using principal component analysis of the image sequence; 2) positioning of three landmarks and robust tracking of these points using a multi-pyramidal refined optical flow approach; 3) estimation of quantitative parameters indicating left and right fractions of mobility, and motion symmetry.

Results provided by image processing were compared to those obtained by a trained ultrasound operator. Detection of extreme images was accurate; tracking of landmarks was reliable in 80%. Motion symmetry indices showed similar values for controls and patients without RP. Fraction of mobility was reduced in cases of RP. Thus, appropriate combining of these two parameters helped in the detection of RP.

Laryngeal ultrasound combined with appropriate image processing helped in the diagnosis of recurrent nerve paralysis and could be proposed as a first–line method.

9414-95, Session PS2

Automatic detection of larynx cancer from contrast-enhanced magnetic resonance images

Trushali P. Doshi, John J. Soraghan, Univ. of Strathclyde (United Kingdom); Derek Grose, Gartnavel Hospital (United Kingdom); Kenneth MacKenzie, NHS Greater Glasgow and Clyde (United Kingdom); Lykourgos Petropoulakis, Univ. of Strathclyde (United Kingdom)

Detection of larynx cancer from medical imaging is important for the quantification and for the definition of target volumes in radiotherapy treatment planning (RTP). Magnetic resonance (MR) imaging is being increasingly used in RTP due to its high resolution and excellent soft tissue contrast. Manually detecting larynx cancer from sequential MR images is time consuming, tedious and subjective. Developing automatic detection system is a challenging task due to different sizes and shapes of cancer, fuzzy boundaries of cancer regions, geometric variability due to the disease and presence of the throat region. This paper presents a new automatic algorithm for the detection of larynx cancer from gadolinium-enhanced T1-weighted (T1+Gd) MR images to assist radiation oncologists in RTP. T1+Gd MR images are pre-processed to reduce data size and increase contrast between different tissues. Clusters with cancer regions are detected from this pre-processed images using spatial fuzzy c-means clustering. Normal tissues are eliminated from this clusters using morphological operations and knowledge that cancer region is near the throat region. Comparison of this automatic detection system with manual clinical detection on real T1+Gd axial MR images of 2 patients (24 MR images) with visible larynx cancer shows average dice similarity coefficient of 0.78±0.04 and average root mean square error of 1.82±0.28 mm. Experimental results show that this automatic system with further modifications can assist radiation oncologists in RTP by obtaining quantifiable and repeatable detection results in a particular time-efficient and objective fashion.

9414-96, Session PS3

Quantitative assessment of smoking-induced emphysema progression in longitudinal CT screening for lung cancer

Hidenobu Suzuki, Ryuji Mizuguchi, Univ. of Tokushima (Japan); Mikio Matsuhiro, Univ of Tokushima (Japan); Yoshiki Kawata, Noboru Niki, Univ. of Tokushima (Japan); Yasutaka Nakano, Shiga Univ. of Medical Science (Japan); Hironobu Ohmatsu, Masahiko Kusumoto, Takaaki Tsuchida, National Cancer Ctr. Hospital East (Japan); Kenji Eguchi, Teikyo Univ. (Japan); Masahiro Kaneko, Tokyo Health Service Assoc. (Japan); Noriyuki Moriyama, Tokyo Midtown Medical Ctr. (Japan)

Computed tomography has used for assessing structural abnormalities associated with emphysema. It is important to develop a robust CT based imaging biomarker that would allow for quantification of emphysema progression in early stage. This paper presents effect of smoking on emphysema progression using annual changes of low attenuation volume (LAV) by each lung lobe acquired from low-dose CT images in longitudinal screening for lung cancer. Progression of emphysema was assessed by statistical analysis of the annual changes represented by linear regression of LAV percentage. This method was applied to 176 participants in lung cancer CT screening for five years (15 nonsmokers, 66 past smokers, and 95 current smokers). The initial results showed that both of pack-year and LAV% are useful to classify current smokers with rapid progression of emphysema (0.33%/year, p<0.05). This paper demonstrates effectiveness in diagnosis and prognosis of early emphysema in CT screening for lung cancer.

9414-97, Session PS3

A novel spherical shell filter for reducing false positives in automatic detection of pulmonary nodules in thoracic CT scans

Sil van de Leemput, Frank Dorssers, Radboud Univ. Nijmegen (Netherlands); Babak Ehteshami Bejnordi, Radboud Univ. Nijmegen Medical Ctr. (Netherlands)

Early detection of pulmonary nodules is crucial for improving prognosis of patients with lung cancer. Computer-aided detection of lung nodules in thoracic computed tomography (CT) scans has a great potential to enhance the performance of the radiologist in detecting nodules. In this paper we present a computer-aided lung nodule detection system for computed tomography (CT) scans that works in three steps. The system first segments the lung using thresholding and hole filling. From this segmentation the system extracts candidate nodules using Laplacian of Gaussian. To reject false positives among the detected candidate nodules, multiple established features are calculated. We propose a novel feature based on a spherical shell filter, which is specifically designed to distinguish between vascular structures and nodular structures. The performance of the proposed CAD system was evaluated by partaking in the ANODE09 challenge, which presents a platform for comparing automatic nodule detection programs. The results from the challenge show that our CAD systems ranks third among the submitted works, demonstrating the efficacy of our proposed CAD system. The results also show that our proposed spherical shell filter in combination with conventional features can significantly reduce the number of false positives from the detected candidate nodules.

9414-98, Session PS3

An outlier filtering approach for machine sourced weak segmentations

Elza Margolin, Daniela S. Raicu, Jacob D. Furst, DePaul Univ. (United States)

Analysis of medical images by radiologists is often a time consuming and costly process. Computer Aided diagnosis (CAD) systems can be used to provide second opinion and assist radiologists in diagnosis. Weak segmentation CAD (WSCAD) can be used to predict semantic characteristics of lung nodules better than or as well as expert radiologists. Our system takes a crowdsourcing approach to WSCADs – that is, the idea that multiple weak segmentations (machine sourcing) can be used to create predictions with the same quality as an expert . We propose that the use of a large amount of machine sourced segmentations will perform better than just a few weak segmentations. In addition, we investigated the idea that outliers filtering will better performance of the WSCAD. Three sets of segmentations were created for this experiment: a set with a few weak segmentations, a set with a large amount of machine sourced segmentations that included outliers, and a set that did not include outliers. Features were extracted from each set and fed into an ensemble classifier. All sets were then compared to a referenced truth that was generated based on radiologists' outlines. It was found that classification based on WSCADs performed as well or better than classification based on radiologists' outlines. In addition, WSCADs with more weak segmentations generate better results. In contrast, the removal of outliers from the set of segmentations does not improve the result further.

9414-99, Session PS3

Segmentation of interstitial lung disease patterns in HRCT images

Jatindra K. Dash, Vaddepalli Madhavi, Sudipta Mukhopadhyay, Indian Institute of Technology Kharagpur (India); Niranjan Khandelwal, Postgraduate Institute of Medical Education & Research (India); Prafulla Kumar, Department of Electronics & Information Technology (India)

Automated segmentation of pathological bearing region is the first step towards the development of lung CAD. Most of the work reported in the literature related to automated analysis of lung tissue aims towards classification of fixed sized block into one of the classes. This block level classification of lung tissues in the image never results in accurate or smooth boundaries between different regions. In this work, effort is taken to investigate the performance of three automated image segmentation algorithms those results in smooth boundaries among lung tissue patterns commonly encountered in HRCT images of the thorax. A public database that consists of HRCT images taken from patients affected with Interstitial Lung Diseases (ILDs) is used for the evaluation. The algorithms considered are Markov Random Field (MRF), Gaussian Mixture Model (GMM) and Mean Shift (MS). 2-fold cross validation approach is followed for the selection of the best parameter value for individual algorithm as well as to evaluate the performance of all the algorithms. Mean shift algorithm is observed as the best performer in terms of Jaccard Index, Modified Hausdorff Distance, accuracy, Dice Similarity Coefficient and execution speed.

9414-100, Session PS3

Semi-automated segmentation of solid and GGO nodules in lung CT images using vessel-likelihood derived from local foreground structure

Atsushi Yaguchi, Tomoya Okazaki, Tomoyuki Takeguchi, Toshiba Corp. (Japan); Sumiaki Matsumoto, Yoshiharu Ohno, Kobe Univ. Graduate School of Medicine (Japan); Kota Aoyagi, Hitoshi Yamagata, Toshiba Medical Systems Corp. (Japan)

Reflecting global interest in lung cancer screening, considerable attention has been paid to automatic segmentation and volumetric measurement of lung nodules on CT. Ground glass opacity (GGO) nodules deserve special consideration in this context, since it has been reported that they are more likely to be malignant than solid nodules. However, due to relatively low contrast and indistinct boundaries of GGO nodules, segmentation is more difficult for GGO nodules compared with solid nodules. To overcome this difficulty, we propose a method for accurately segmenting not only solid nodules but also GGO nodules without prior information about nodule types. First, the histogram of CT values in pre-extracted lung regions is modeled by a Gaussian mixture model and a threshold value for including high-attenuation regions is computed. Second, after setting up a region of interest around the nodule seed point, foreground regions are extracted by using the threshold and quick-shift-based mode seeking. Finally, for separating vessels from the nodule, a vessel-likelihood map derived from tubeness of foreground regions is computed, and a region growing scheme starting from the seed point is applied to the map with the aid of fast marching method. Experimental results using an anthropomorphic chest phantom showed that our method yielded generally lower volumetric measurement errors for both solid and GGO nodules compared with other methods reported in preceding studies conducted using similar technical settings. Also, our method allowed reasonable segmentation of GGO nodules in low-dose images and could be applied to clinical CT images including part-solid nodules.

9414-101, Session PS3

Improved pulmonary nodule classification utilizing lung parenchyma texture features

Samantha K. Dilger, The Univ. of Iowa Hospitals and Clinics (United States); Alexandra Judisch, Univ. of Iowa Hospitals

and Clinics (United States); Johanna Uthoff, Emily Hammond, John D. Newell, Jessica C. Sieren, The Univ. of Iowa Hospitals and Clinics (United States)

Current computer-aided diagnosis (CAD) models developed to determine the malignancy of pulmonary nodules characterize the nodule's shape, density, and border. Analyzing the lung parenchyma surrounding the nodule is an area that has been minimally explored. We hypothesize that improved classification of nodules can be achieved through the inclusion of features quantified from the surrounding lung tissue. From computed tomography (CT) data, feature extraction techniques were developed to quantify the parenchymal and nodule textures, including a three-dimensional application of Laws' Texture Energy Measures. Border irregularity was investigated using ray-casting and rubber-band straightening techniques, while histogram features characterized the densities of the nodule and parenchyma. The feature set was reduced by stepwise feature selection to a few independent features that best summarized the dataset. Using leave-one-out cross-validation, a neural network was used for classification. The CAD tool was applied to 50 nodules (24 malignant, 26 benign) from high-resolution CT scans. 47 features, including 36 parenchymal features, were statistically significant, with both nodule and parenchyma features selected for classification, yielding an area under the ROC curve (AUC) of 0.9183. This was compared to classification solely based on the nodule yielding an AUC of 0.9006. These preliminary results show an increase in performance when the surrounding parenchyma is included in analysis. While modest, the improvement and large number of significant parenchyma features supports our hypothesis that the parenchyma contains meaningful data that can assist in CAD development.

9414-102, Session PS3

Quantification of pulmonary vessel diameters in low-dose CT images

Rina D. Rudyanto, Arrate Muñoz-Barrutia, Carlos Ortiz de Solórzano, Univ. de Navarra (Spain)

Accurate quantification of vessel diameter in low-dose Computer Tomography (CT) images is important to study pulmonary diseases, in particular for the diagnosis of vascular diseases and the characterization of morphological vascular remodeling in Chronic Obstructive Pulmonary Disease (COPD). In this study, we objectively compare several vessel diameter estimation methods using a physical phantom. Five solid tubes of differing diameters (from 0.898 to 3.980 mm) were embedded in foam, simulating vessels in the lungs. To measure the diameters, we first extracted the vessels using either of two approaches: vessel enhancement using multi-scale Hessian matrix computation, or explicitly segmenting them using intensity threshold. We implemented six methods to quantify the diameter: three estimating diameter as a function of scale used to calculate the Hessian matrix; two calculating equivalent diameter from the cross-section area obtained by thresholding the intensity and vesselness response, respectively; and finally, estimating the diameter of the object using the Full Width Half Maximum (FWHM). We find that the accuracy of frequently used methods estimating vessel diameter from the multi-scale vesselness filter depends on the range and the number of scales used. Moreover, these methods still yield a significant error margin on the challenging estimation of the smallest diameter (on the order or below the size of the CT point spread function). The performance of the thresholding-based methods depends on the value of the threshold. Finally, we observe that a simple adaptive thresholding approach can achieve a robust and accurate estimation of the smallest vessels diameter

9414-103, Session PS3

Automated detection of lung tumors in PET/CT images using active contour filter

Atsushi Teramoto, Hayato Adachi, Masakazu Tsujimoto, Fujita Health Univ. (Japan); Hiroshi Fujita, Gifu Univ.

(Japan); Katsuaki Takahashi, Osamu Yamamuro, Tsuneo Tamaki, East Nagoya Imaging Diagnosis Ctr. (Japan); Masami Nishio, Toshiki Kobayashi, Nagoya Radiological Diagnosis Ctr. (Japan)

In a previous study, we developed a hybrid tumor detection method that used both computed tomography (CT) and positron emission tomography (PET) images. However, similar to existing computer-aided detection (CAD) schemes, it was difficult to detect low-contrast lesions that touch to the normal organs such as the chest wall or blood vessels in the lung. In the current study, we proposed a novel lung tumor detection method that uses active contour filters to detect the nodules deemed "difficult" in previous CAD schemes. The proposed scheme detects lung tumors using both CT and PET images. As for the detection in CT images, the massive region was first enhanced using an active contour filter (ACF), which is a type of contrast enhancement filter that has a deformable kernel shape. The kernel shape involves closed curves that are connected by several nodes that move iteratively in order to enclose the massive region. The final output of ACF is the difference between the maximum pixel value on the deformable kernel, and pixel value on the center of the filter kernel. Subsequently, the PET images were binarized to detect the regions of increased uptake. The results were integrated, followed by the false positive reduction using 21 characteristic features and three support vector machines. In the experiment, we evaluated the proposed method using 100 PET/CT images. More than half of nodules missed using previous methods were accurately detected. The results indicate that our method may be useful for the detection of lung tumors using PET/CT images.

9414-104, Session PS3

Peripleural lung disease detection based on multi-slice CT images

Mikio Matsuhiro, Hidenobu Suzuki, Yoshiki Kawata, Noboru Niki, Univ. of Tokushima (Japan); Yasutaka Nakano, Shiga Univ. of Medical Science (Japan); Hironobu Ohmatsu, Masahiko Kusumoto, Takaaki Tsuchida, National Cancer Ctr. Hospital East (Japan); Kenji Eguchi, Teikyou Univ. School of Medicine (Japan); Masahiro Kaneko, Tokyo Health Service Association (Japan)

Detection peripleural lung disease is difficult to become out of lung region. Because lung extraction is often performed based on threshold processing. The proposed method uses inner cavity of bone covers pripleural lung diseased cases such as lung cancer, pleural effusion and pleural plaque. Peripleural lung disease detection is described as follows. We extract bone region based on inner cavity of bone. We extract thoracic inner region by restricted delaunay method for bone region. Candidate peripleural lung disease is extracted from thoracic inner region without air region. We detect peripleural lung disease from candidate peripleural lung disease using threshold processing and shape analysis by 3D curvature. We applied this method to 50 cases include 39 peripleural lung disease. This method could detect 39 peripleural lung disease and there are 2.9 false positive per case.

9414-45, Session PS4

Prostate cancer detection from model-free T1-weighted time series and diffusion imaging

Nandinee F. Haq, Piotr Kozlowski, S. Larry Goldenberg, Edward C. Jones, Silvia D. Chang, The Univ. of British Columbia (Canada); Mehdi Moradi, The Univ. of British Columbia (Canada) and IBM Research - Almaden (United States)

The combination of Dynamic Contrast Enhanced (DCE) images with diffusion MRI has shown great potential in prostate cancer detection. The parameterization of DCE images to generate cancer markers is traditionally performed based on pharmacokinetic modeling. However, pharmacokinetic models make simplistic assumptions about the tissue perfusion process, require the knowledge of contrast agent concentration in a major artery, and the modeling process is sensitive to noise and fitting instabilities. We address this issue by extracting features directly from the DCE T1-weighted time course without modeling. In this work, we employed a set of data-driven features generated by mapping the DCE T1 time course to its principal component space with diffusion MRI feature to detect prostate cancer. The optimal set of DCE features is extracted with sparse regularized regression through a Least Absolute Shrinkage and Selection Operator (LASSO) model. We show that when our proposed features are used within the mpMRI protocol to replace the pharmacokinetic parameters, the area under ROC curve is 0.91 for peripheral zone classification and 0.87 for whole gland classification. We were able to correctly classify 32 out of 35 peripheral tumor areas identified in the data when the proposed features were used with support vector machine classification. The proposed feature set was used to generate cancer likelihood maps for the prostate gland.

9414-105, Session PS4

Context-specific method for detection of soft-tissue lesions in non-cathartic low-dose dual-energy CT colonography

Janne J. Näppi, Massachusetts General Hospital (United States); Daniele Regge, Institute for Cancer Research and Treatment (Italy); Hiroyuki Yoshida, Massachusetts General Hospital (United States)

In computed tomographic colonography (CTC), orally administered fecal tagging is used to indicate residual feces and fluid that could hide or imitate lesions on CTC images. However, the presence of fecal tagging can change the visual appearance of lesions on CTC images. This can affect the computation of features that are used for detection and false-positive (FP) reduction of lesions, thereby reducing the accuracy of computer-aided detection (CADe). We developed a context-specific method that performs the detection of lesions separately on lumen regions covered by air and on those covered by fecal tagging. For pilot evaluation, the context-specific method was integrated into a dual-energy CADe (DE-CADe) scheme and evaluated by use of leave-one-patient-out evaluation on 66 clinical non-cathartic low-dose DE-CTC cases. The cases were acquired at an effective radiation dose of 0.75 mSv per scan position and reconstructed by use of iterative image reconstruction at 0.6 – 1.0 mm intervals. There were 22 colonoscopy-confirmed lesions 6 mm or larger in size in 21 patients. The DE-CADe system detected 96% of the lesions at a median of 6 FP detections per patient. The results indicate that the use of context-specific detection can yield high detection accuracy of CADe in non-cathartic low-dose DE-CTC.

9414-107, Session PS5

A novel algorithm for segmenting retinal vessels depicted on fundus photographs

Yi Zhen, National Engineering Research Ctr. for Ophthalmology (China); Xin Meng, Univ. of Pittsburgh (United States); Bin Zheng, The Univ. of Oklahoma (United States); Ningli Wang, National Engineering Research Ctr. for Ophthalmology (China); Jiantao Pu, Univ. of Pittsburgh (United States)

PURPOSE:

A large variety of systematic diseases (e.g., diabetes, hyptertension, arteriosclerosis, cardiovascular diseases, and stroke) and retinal diseases (e.g., retinopathy of prematurity, glaucoma, and maculopathy) are closely associated with retinal vessels. In order to aid in an efficient and objective quantification of retinal vessel morphology, a novel algorithm was described to accurately delineate the boundary of retinal vessels

METHODS:

The developed scheme consists of three steps in implementation. The first step is to extract the green channel from a color retinal fundus photograph in RGB format, because this channel provides the highest contrast between vessels and background. Thereafter, a multiscale directional contrast quantification strategy is used to transform the green channel image into a contrast image, where the value of each pixel denotes its contrast with the local background. As vessel enhancement procedure, this strategy overcomes the variability of vessels in appearance (i.e., intensity and size) at different locations of a fundus image. Third, a differential fusion strategy was used to combine the results identified at different scales and meanwhile remove noisy regions. Finally, a simple filling operation is used to fix the missing of vessels due to the existence of central light reflex. Three publically available databases, namely DRIVE, STARE, and HRF that contain manual segmentation results, were used to quantitatively assess the performance of the developed strategy, including sensitivity, specificity, and accuracy.

RESULTS:

The performance measures on the three publicly available databases were presented in Tables 1-3. Our experimental results demonstrate the reliability of this scheme in identifying small retinal vessels in particular in the presence of diseases.

CONCLUSION:

A fully automated computer algorithm was described in this study to identify retinal vessels depicted on color fundus photographs. Three components are involved in implementation, including contrast quantification, image fusion, and central light reflex region filling. As compared with available methods, this scheme is novel and has a couple of advantages, such as simplicity, reliability, accuracy. In particular, it is relatively insensitive to image noise or artifacts or the presence of diseases. Experiments on three publically available databases that contain both diseased and healthy subjects and both low and high resolution images validated its feasibility and performance.

9414-108, Session PS5

Automated detection of Schlemm's canal in spectral-domain optical coherence tomography

Manu Tom, Vignesh Ramakrishnan, Univ. Hospital Aachen (Germany); Christian Oterendorp, Georg-August-Univ. Göttingen (Germany); Thomas M. Deserno, Univ. Hospital Aachen (Germany)

Recent advances in optical coherence tomography (OCT) technology allow in vivo imaging of the complex network of intra-scleral aqueous veins in the anterior segment of the eye. Pathological changes in this network, draining the aqueous humor from the eye, are considered to play a role in intraocular pressure elevation, which can lead to glaucoma, one of the major causes of blindness in the world. Through acquisition of OCT volume scans of the anterior eye segment we aim at reconstructing the three dimensional network of aqueous veins in healthy and glaucomatous eyes. We present a novel algorithm for segmentation of the 3D vessel system in human Schlemm's canal analyzing frames of spectral domain OCT (SD-OCT) of the eye's surface in either horizontal or vertical orientation. Distortions such as vertical stripes are caused by the superficial blood vessels in the conjunctiva and the episclera. They are removed in the discrete Fourier domain, masking particular frequencies. Feature-based rigid registration of these noise-filtered images is then performed using the scale-invariant feature transform. Segmentation of the vessels deep in the sclera originating at or in the vicinity of or having indirect connection to the Schlemm's canal is then performed with a distance regularized level set evolution. The segmented vessels are visualized in 3D.

9414-109, Session PS5

Computer-based assessment of right ventricular regional ejection fraction in patients with repaired Tetralogy of Fallot

Soo Kng Teo, Sum-Thai Wong, May-Ling Tan, Yi Su, A*STAR Institute of High Performance Computing (Singapore); Liang Zhong, Ru-San Tan, National Heart Ctr. Singapore (Singapore) and Duke-NUS Graduate Medical School (Singapore)

After surgical repair for Tetralogy of Fallot (TOF), most patients experience long-term complications as the right ventricle (RV) undergoes progressive remodeling that eventually affect heart functions. Thus, post-repair surgery is required to prevent further deterioration of RV functions that may result in malignant ventricular arrhythmias and mortality. The timing of such post-repair surgery therefore depends crucially on the quantitative assessment of the RV functions. Current clinical indices for such functional assessment measure global properties such as RV volumes and ejection fraction. However, these indices are less than ideal as regional variations and anomalies are obscured. Therefore, we sought to (i) develop a quantitative method to assess RV regional function using regional ejection fraction (REF) based on a 13-segment model, and (ii) evaluate the effectiveness of REF in discriminating 6 repaired TOF patients and 6 normal control based on cardiac magnetic resonance (CMR) imaging. We observed that the REF for the individual segments in the patient group is significantly lower compared to the control group (P < 0.05 using a 2-tail student t-test). In addition, we also observed that the aggregated REF at the basal, mid-cavity and apical regions for the patient group is significantly lower compared to the control group (P < 0.001 using a 2-tail student t-test). The results suggest that REF could potentially be used as a quantitative index for assessing RV regional functions. The computational time per data set is approximately 60 seconds, which demonstrates our method's clinical potential as a real-time cardiac assessment tool.

9414-110, Session PS5

Automatic generation of endocardial surface meshes with 1-to-1 correspondence from cine-MR images

Yi Su, Soo Kng Teo, Chi Wan Lim, A*STAR Institute of High Performance Computing (Singapore); Liang Zhong, Ru-San Tan, National Heart Ctr. Singapore (Singapore) and Duke-NUS Graduate Medical School (Singapore)

In this work, we develop an automatic method to generate a set of 4D 1-to-1 corresponding surface meshes of the left ventricle (LV) endocardial surface which are motion registered over the whole cardiac cycle. These 4D meshes have 1-to-1 point correspondence over the entire set, and is suitable for advanced computational processing, such as shape analysis, motion analysis and finite element modelling. The inputs to the method are the set of 3D LV endocardial surface meshes of the different frames/phases of the cardiac cycle. Each of these meshes is reconstructed independently from border-delineated MR images and they have no correspondence in terms of number of vertices/points and mesh connectivity. To generate point correspondence, the first frame of the LV mesh model is used as a template to be matched to the shape of the meshes in the subsequent phases. There are two stages in the mesh correspondence process: (1) a coarse matching phase, and (2) a fine matching phase. In the coarse matching phase, an initial rough matching between the template and the target is achieved using a radial basis function (RBF) morphing process. The feature points on the template and target meshes are automatically identified using a 16-segment nomenclature of the LV. In the fine matching phase, a progressive mesh projection process is used to conform the rough estimate to fit the exact shape of the target. In addition, an optimization-based smoothing process is used to achieve superior mesh quality and continuous point motion.

9414-111, Session PS5

Semi-automated measurements of heart-to-mediastinum ratio on 123I-MIBG myocardial scintigrams by using image fusion method with chest X-ray images

Ryosuke Kawai, Takeshi Hara, Gifu Univ. (Japan); Tetsuro Katafuchi, Gifu Univ. of Medical Science (Japan); Tadahiko Ishihara , Gifu Univ. Hospital (Japan); Xiangrong Zhou, Gifu Univ. School of Medicine (Japan); Chisako Muramatsu, Gifu Univ. (Japan); Yoshiteru Abe, Yaizu City Hospital (Japan); Hiroshi Fujita, Gifu Univ. (Japan)

MIBG (Iodine-131-meta-iodobenzylguanidine) is a radioactive medicine to help diagnose not only myocardium diseases but also Parkinson's Diseases (PD) and Dementia with Lewy Bodies (DLB). The difficulty of the segmentation around myocardium decreases the consistency of the measurement results. One of the most common measurements is the ratio of the uptake values of heart to mediastinum (H/M). The ratio is stable when the uptake value from myocardium region is clear, but it is not reliable when the myocardium region is unclear because of the low uptake value. The purpose of this study was to develop a new measuring method by using image fusion technique of three modalities of MIBG scintigrams, 201-Tl scintigrams, and chest radiograms. Our automated method consists of following steps: 1) Constructing left ventricular map (LV map) from 201-Tl myocardium image database, 2) Determination of heart and mediastinum regions on chest radiograms, 3) Image fusion of chest radiograms and MIBG scintigrams, 4) H/M measurement on MIBG scintigrams by using locations of heart and mediastinum determined on the chest radiograms. Bland-Altman plot was employed to compare our measurement result with a gold standard measured by a manual procedure. As a result of the comparison, the 95% confidence interval of the difference between the two measurements was -0.072 to 0.018. The correlation between the two measurements was 0.84. The correlation of myocardium regions between our method and the manual procedure was 0.98. We concluded that our developed method could be used as a reliable measurement for the patients whose uptake in myocardium was low.

9414-112, Session PS5

Myocardial strain estimation from CT: towards computer-aided diagnosis on infarction identification

Ken C. L. Wong, Michael Tee, Marcus Chen, David A. Bluemke, Ronald M. Summers, Jianhua Yao, National Institutes of Health (United States)

Cardiac CT is commonly available in clinical routine, and the regional myocardial strains estimated from CT have the potential for early quantification and detection of cardiac dysfunction. In our framework, the frame-to-frame displacements on the heart surfaces are computed using B-spline deformable image registration based on mutual information, which are enforced as boundary conditions to a hyperelastic biomechanical model to estimate the myocardial strains. Three principal strains and six strains in cylindrical coordinates can be estimated, and their regional strains are computed in terms of the American Heart Association (AHA) nomenclature (17 zones).

We studied the potential of the estimated strains on identifying myocardial infarction in computer-aided diagnosis. Ten canine cardiac CT sequences with artificially induced myocardial infarction were used, with the infarcted regions identified from perfusion CT on the AHA nomenclature. For each subject, the maximum zonal strain magnitude in the whole cardiac cycle was selected for each zone, and the largest one among all 17 zones was used to compute the normalized zonal strains. As infarcted tissues are usually less contractile, in this preliminary study, the zonal strain magnitudes were

used as the inputs to a threshold classifier. The leave-one-subject-out cross validations show that, by using the optimal thresholds computed from ROC curves, the normalized radial strain has the highest performance (TPR: 0.73+/-0.17, FPR: 0.07+/-0.04, AC1 coefficient: 0.74+/-0.15), followed by the normalized first principal strain (TPR: 0.72+/-0.20, FPR: 0.14+/-0.10, AC1 coefficient: 0.66+/-0.20). We also found that the normalized zonal strains outperform the unnormalized ones.

9414-113, Session PS5

Heart rate measurement based on face videosequence

Fang Xu, Qin-Wu Zhou, Xi'an Jiaotong Univ. (China); Peng Wu, Tsinghua Univ. (China); Xiaofeng Yang, Winship Cancer Institute, Emory Univ. (United States); Xing Chen, Hong-jian Yan, Xi'an Jiaotong Univ. (China)

We proposed a new non-contact heart rate measurement method based on photoplethysmography (PPG) theory. With this method we can measure heart rate remotely with a camera and ambient light. We collected video sequences of subjects with a camera, and detected remote PPG signals through video sequences. Then we used two methods to exact the heart rate. One is the method of independent component analysis using the blind source separation technology. After the process of zero mean and whitening, using FastICA algorithm, we calculated the three separated constituents by iteration. At last, we analyzed the spectrum, and extracted the heart rate component in the second constituent. The other heart rate extraction algorithm is based on the cross-correlation power spectrum which is used for the first time in the study of remote PPG signals in our work. Through the baseline removal and band-pass filtering of the signals, analyzing the cross-correlation power spectrum, enhancing periodic component, suppressing the non-periodic component interference, we successfully extract the heart rate. We did the conformity assessment analysis of the heart rate extraction results of cross-correlation power spectrum method and that of the fingertip oximeter. The results show that the two measurement methods have good consistency. Both of the extraction algorithms can effectively extract heart rate component. Compared with the blind source separation technique, the cross-correlation power spectrum method has clearer physical meaning and lower computational complexity. This method has a good prospect for the application in the field of home medical devices and mobile health devices.

9414-114, Session PS5

Detection of hypertrophic cardiomyopathy in left ventrical based on cardiac MR Imaging

Xi Liang, IBM Research – Australia (Australia); Rahil Garnavi, IBM Research - Australia (Australia); Sisi Liang, Simon Wail, IBM Research – Australia (Australia); Prasanth Prasanna, IBM Research, United States (United States)

This paper proposes a novel method to detect Hypertrophic Cardiomyopathy (HCM) in left ventrical using cardiac MRI Images. The proposed method applies mathematical morphology to identify regions greater than 15 mm. We measure the thickness of the LV, defined as the perpendicular line of each pixel on the skeleton circle of the LV. For every successive window of 5 pixels, the regions with thickness larger than 15mm are identified as hypertrophy. The method has been tested on 12 patients with HCM, and the proposed method is able to successfully detect 9 patients, i.e. 75% sensitivity.

9414-115, Session PS5

Application and evaluation of comprehensive software for analyzing intravascular OCT stent pullbacks

Hong Lu, Case Western Reserve Univ. (United States); Martin Jakl, Univ. Hospital Hradec Králové (Czech Republic); Zhao Wang, Massachusetts Institute of Technology (United States); Kentaro Tanaka, Univ. Hospitals Case Medical Ctr. (United States); Soumya Ray, Case Western Reserve Univ. (United States); Pavel Cervinka, Univ. Hospital Hradec Králové (Czech Republic); Marco Costa, Univ. Hospitals Case Medical Ctr. (United States); Andrew M. Rollins, Case Western Reserve Univ. (United States); Hiram G. Bezerra, Univ. Hospitals Case Medical Ctr. (United States); David L. Wilson, Case Western Reserve Univ. (United States)

Intravascular optical coherence tomography (OCT) is widely used to assess stent tissue coverage and malapposition in clinical stent trials. Currently, stent analysis is done manually with limited software assistance, requiring 6-12 hours per pullback and subject to inter- and intra-observer variability. We developed image analysis algorithms to automate objective stent analysis. Guide wire artifact and lumen boundary were segmented using dynamic programming. Advanced machine learning algorithms were employed to detect stent struts and determine the presence of strut tissue coverage. Strut-level tissue coverage thickness and malapposition distance and frame-level NIH and malapposition areas were automatically quantified. Algorithms were incorporated into a comprehensive software package, OCT image visualization and analysis toolkit for stent analysis (OCTivat-Stent). Convenient manual review and editing tools were included for refinement of automatic results. The software was trained on previous manually annotated OCT data, fixed, and used to analyze 292 stent pullbacks in the ROBUST study (NCT00888758.) A cardiologist reviewed and edited automated analysis. The concordance correlation coefficients between automatically and manually measured stent and lumen areas were 0.97 and 0.99, respectively. Sensitivity for strut detection was 89% and precision was 99%. 18% of human-classified uncovered and 1% of covered struts were mislabeled by software. Compared to fully manual analysis, average inter-observer agreement for sensitivity/specificity of strut classification was improved from 62%/92% to 74%/98% using the software. Analyst time for a full stent analysis was reduced from 6-12 hours to 27+/-18 minutes. Application of this software to stent trials should enable faster, larger, and more reproducible studies.

9414-116, Session PS5

Characterization of vascular tree architecture using the Tokunaga taxonomy

Miguel A. Galarreta-Valverde, Univ. de São Paulo (Brazil); Jihan M. Zoghbi, University of São Paulo (Brazil); Fabricio Pereira, Ctr. Hospitalier Régional Univ. de Nîmes (France); Jean-Paul Beregi, Univ. Hospital Center of Nîmes and Research Team EA 2415 (France) and Montpellier Univ. (France); Choukri Mekkaoui, Harvard Medical School, Massachusetts General Hospital (United States) and Ctr. Hospitalier Régional Univ. de Nîmes, Montpellier 1 Univ. (France); Marcel P. Jackowski II, Univ. de São Paulo (Brazil)

The diagnosis of cardiovascular disease is usually assisted by magnetic resonance angiography (MRA) or computed tomography angiography (CTA) imaging. The identification of abnormal vascular architecture from three-dimensional angiographic images is therefore crucial to the diagnosis of vascular disease. Automated detection and quantification of vascular

architecture thus holds significant clinical value. In this work, we employ a Lindenmayer system to represent vascular trees from three-dimensional angiographic images and describe a quantitative measure based on the Tokunaga taxonomy to differentiate vascular architectures. Synthetic vessel architectures with varying bifurcation patterns were compared and results showed that this architectural measure is proportional to the level of branching. In real MRA images, this measure was able to differentiate between normal and abnormal intracerebral vasculature containing an aneurysm. Hence, this methodology not only allows for compact representation of vascular architectures but also provides a quantitative metric of bifurcation complexity, which may characterize different types of vascular abnormalities.

9414-117, Session PS6

Bone age assessment meets SIFT

Muhammad Kashif, Univ. Hospital Aachen (Germany); Stephan Jonas, Daniel Haak, Thomas M. Deserno, RWTH Aachen Univ. (Germany)

Bone age assessment (BAA) is a method of determining the skeletal maturity and finding the growth disorder in the skeleton of a person. BAA is frequently used in pediatric medicine but also a time-consuming and cumbersome task for a radiologist. Conventionally, the Greulich & Pyle and the Tanner & Whitehouse methods are used for bone age assessment, which are based on visual comparison of left hand radiographs with a standard atlas. We present a novel approach for automated bone age assessment, combining scale invariant feature transform (SIFT) features and support vector machine (SVM) classification. In this approach, (i) data is grouped into 30 classes to represent the age range of 0-18 years, (ii) 14 epiphyseal ROIs are extracted from left hand radiographs, (iii) multi-level image thresholding, using Otsu method, is applied to specify keypoints on bone and osseous tissues of eROIs, (iv) SIFT features are extracted for specified keypoints for each eROI of hand radiograph, and (v) classification is performed using a multi-class extension of SVM. A total of 1101 radiographs of University of Southern California are used in training and testing phases using 5-fold cross-validation. Evaluation is performed for two age ranges (0-18 years and 2-17 years) for comparison with previous work and the commercial product BoneXpert, respectively. Results are improved significantly, where a mean error of 0.67 years for age range 0-18 years and mean error of 0.68 years for age range 2-17 years are obtained. Accuracy of 98.09 %, within the range of two years is achieved.

9414-118, Session PS6

A novel framework for the temporal analysis of bone mineral density in metastatic lesions using CT images of the femur

Tom H. Knoop, Univ. Twente (Netherlands); Loes C. Derikx, Nico Verdonschot, Orthopaedic Research Lab. (Netherlands); Cornelis H. Slump, Univ. Twente (Netherlands)

In the more progressive stages of cancer, metastatic lesions in the femur often develop. The accompanying risk of fracture dramatically affects the quality of life of the patient. Radiotherapy is often administered as palliative treatment to restore the bone around the lesion. It is thought to affect the bone mineralization of the treated region, but the quantitative relation between radiotherapy and femur mineralization remains unclear. To investigate this relationship, a new framework for the longitudinal analysis of CT-scans of patients receiving radio therapy is presented.

The implemented framework is capable of automated calibration of Hounsfield Units to calcium equivalent values and the estimation of a prediction interval per scan. Other features of the framework are temporal registration of femurs using elastix transformation of arbitrary Regions Of Interests (ROI), and extraction of metrics for analysis. The modular Matlab based approach aides easy adaptation to the pertinent questions of an explorative phase of the research.

For validation, an in vitro model consisting a human cadaver femur with a milled hole in the intertrochanteric region has been created. This hole was gradually stacked with plates of PMMA with variable radiopaqueness. Using a Kolmogorov-Smirnov (KS) test, changes in density distribution due to an increase of the calcium concentration could be discriminated. Changes in 8% of a 21 cm ROI around the artificial lesion from 888±57 mg/ml to 1000±80mg/ml hydroxyapatite could be statistically proven using the proposed framework. In conclusion, the newly developed framework proves a useful and fexible tool for the analysis of longitudinal CT data.

9414-119, Session PS6

Spinal focal lesion detection in multiple myeloma using multimodal image features

Andrea Fränzle, Deutsches Krebsforschungszentrum (Germany); Jens Hillengaß, Ruprecht-Karls-Univ. Heidelberg (Germany) and Deutsches Krebsforschungszentrum (Germany); Rolf Bendl, Deutsches Krebsforschungszentrum (Germany) and Heilbronn Univ. (Germany)

Multiple myeloma is a tumor disease in the bone marrow that affects the skeleton systemically, i.e. multiple lesions can occur in different sites in the skeleton. To quantify overall tumor mass for determining degree of disease and for analysis of therapy response, volumetry of all lesions is needed. Since the large amount of lesions in one patient impedes manual segmentation of all lesions, quantification of overall tumor volume is not possible until now. Therefore development of automatic lesion detection and segmentation methods is necessary. Since focal tumors in multiple myeloma show different characteristics in different modalities (changes in bone structure in CT images, hypointensity in T1 weighted MR images and hyperintensity in T2 weighted MR images), multimodal image analysis is necessary for the detection of focal tumors. In this paper a pattern recognition approach is presented that identifies focal lesions in lumbar vertebrae based on features from T1 and T2 weighted MR images. Image voxels within bone are classified using random forests based on plain intensities and intensity value derived features (maximum, minimum, mean, median) in a 5 x 5 neighborhood around a voxel from both T1 and T2 weighted MR images. A test data sample of lesions in 8 lumbar vertebrae from 4 multiple myeloma patients can be classified at an accuracy of 95 % (using a leave-one-patient-out test). The approach provides a reasonable delineation of the example lesions. This is an important step towards automatic tumor volume quantification in multiple myeloma.

9414-120, Session PS6

Knee osteoarthritis image registration: data from the Osteoarthritis Initiative

Jorge I. Galván-Tejada, Instituto Tecnológico y de Estudios Superiores de Monterrey (Mexico); José M. Celaya-Padilla, Victor Treviño, José G. Tamez-Peña, Instituto Tecnológico y de Estudios Superiores de Monterrey (Mexico)

Knee osteoarthritis is a very common disease, in early stages, changes in joint structures are shown, some of the most common symptoms are; formation of osteophytes, cartilage degradation and joint space reduction, among others. Based on a joint space reduction measurement, Kellgren-Lawrence grading scale (K&L), is a very extensive used tool to asses radiological OA knee x-ray images, based on information obtained from these assessments, the objective of this work is to correlate the K&L score to the information about the bilateral knee x-ray image registration. Using public data from the Osteoarthritis initiative (OAI), a set of images with

different K&L scores were used to determine a relationship of K&L score and the bilateral asymmetry, in order to measure the asymmetry between the knees, the right knee was registered to match the left knee, then a series of similarity metrics, mutual information, correlation, and mean squared error where computed to correlate the deformation (mismatch) of the knees to the K&L score. Radiological information was evaluated and scored by OAI radiologist groups. The results of the study suggest an association between Radiological K&L score and image registration metrics. Mutual information and correlation between the knees is higher in the early stages, and mean squared error is higher in advanced stages. This association can be helpful to develop a computer aided grading tool.

9414-121, Session PS6

Dynamic cortex stripping for improved vertebral cancellous bone visualization on CT

James Stieger, National Institutes of Health (United States); Joseph E. Burns, Univ. of California, Irvine (United States); Jianhua Yao, Ronald M. Summers, National Institutes of Health (United States)

Vertebral cortex removal through cancellous bone reconstruction (CBR) algorithms on CT has been shown to enhance the detection rate of bone metastases by radiologists and reduce average reading time per case. Removal of the cortical bone provides an unobstructed view of the inside of vertebrae without any anomalous distractions. However, these algorithms rely on the assumption that the cortical bone of vertebrae can be removed without the identification of the endosteal cortical margin. We present a method for the identification of the endosteal cortical margin based on vertebral models and CT intensity information. First, triangular mesh models are created for each vertebra using the marching cubes algorithm. A search region is established along the normal of the surface and the image gradient is calculated at every point along the search region. The location with the greatest image gradient is selected as the corresponding point on the endosteal cortical margin. A smoothing algorithm is then applied to regulate the endosteal surface. In order to analyze the strength of this method, ground truth and control models were created. Our method was shown to significantly reduce the average error from 0.80 mm +/- 0.14 mm to 0.65 mm +/- 0.17 mm (p < 0.0001) when compared to the erosion method. This method can potentially improve visualization of cancellous bone lesions such as metastases, by more accurately identifying the inner wall of the vertebral cortex.

9414-122, Session PS6

Prognosis of intervertebral disc loss from diagnosis of degenerative disc disease

Shuo Li, GE Healthcare (Canada); KengYeow Tay, Victoria Hospital, London Health Sciences Ctr. (Canada); Amy Lin, Western University (Canada); Walt Romano, Said Osman, St. Joseph's Health Care (Canada)

Degenerative Disc Diseas (DDD) is one of the most common causes of low back pain, and is a major factor in limiting the quality of life of an individual usually as they enter older stages of life, the disc degeneration reduces the shock absorption available which in turn causes pain. Disc loss is one of the central processes in the pathogenesis of DDD. In this study, we investigated whether the image texture features quantified from magnetic resonance imaging (MRI) could be appropriate markers for diagnosis of DDD and prognosis of inter-vertebral disc loss. The main objective is to use simple image based biomarkers to perform prognosis of spinal diseases using non-invasive procedures. Our results from 65 sub proved the higher success rates of the combination marker compared to the individual markers and in the future, we will extend the study to other spine regions to allow prognosis and diagnosis of DDD for a wider region.

9414-123, Session PS6

A web-based procedure for liver segmentation in CT images

Rong Yuan, Ming Luo, Luyao Wang, Huazhong Univ. of Science and Technology (China); Qingguo Xie, Huazhong Univ. of Science and Technology (China) and Wuhan National Lab. for Optoelectronics (China)

Liver segmentation in CT images has been acknowledged as a basic and indispensable part in systems of computer aided liver surgery for operation design and risk evaluation. In this paper, we will introduce and implement a web-based procedure for liver segmentation to help radiologists and surgeons get an accurate result efficiently and expediently. Firstly, a novel and automatic segmentation is proposed and accomplished on the high-performance server as initial result. In our method, anatomical features are taken into account to separate the organs adjacent to liver. We use ribs as the landmarks to locate the liver and excise the interfering organs such as heart, stomach and muscle. After this, a segmentation based on region growing is performed. The seeds are generated via histogram analysis automatically and compensating for edge, cusps and holes is added to obtain a better result. The initial segmentation is applied to 10 MICCAI (Medical Image Computing and Computer Assisted Intervention) datasets and 5 clinical datasets. On the fundament of the rapid initial segmentation on the server, desktop-like user interaction is provided by using AJAX technology to meet the requirements of different diagnosis purposes. For the visualization functionality, HTML5 and WebGL are used over the website to present the 2D and 3D results. This procedure seems a promising approach for extraction of liver volumetry of various shapes. Moreover, it is possible for user to access the segmentation wherever the Internet is available without any specific machine.

9414-124, Session PS7

Evaluation of chemotherapy response in ovarian cancer treatment using quantitative CT image biomarkers: a preliminary study

Yuchen Qiu, Maxine Tan, The Univ. of Oklahoma (United States); Scott McMeekin, Theresa Thai, The Univ. of Oklahoma Health Sciences Ctr. (United States); Kathleen Moore, Health Sciences Center, University of Oklahoma (United States); Kai Ding, The Univ. of Oklahoma Health Sciences Ctr. (United States); Hong Liu, Bin Zheng, The Univ. of Oklahoma (United States)

Ovarian cancer is a type of malignant tumor with highest death rate in gynecology. Due to the lack of an effective early screening method, the majority of ovarian cancer patients are diagnosed at advanced stage with metastatic tumors, which need to be treated by chemotherapy after the ovarian surgery. In order to accurately evaluate patients' response to the chemotherapy, we tested a new quantitative image biomarker based assessment method using two sets of CT images which are acquired pre- and post-treatment. To early predict treatment efficacy, post-treatment CT is typically taken within 4 to 6 weeks after starting treatment. Our testing dataset includes 51 tumors originally tracked and assessed by RECIST guideline, for which a 6-month progression-free survival was used as evaluation criterion. A CAD scheme was applied to segment the tumors and compute three features namely, tumor volume, average and standard deviation of tumor intensity. We then computed the difference of these tumor features obtained from pre- and post-treatment CT images of the same patient. After feature normalization, several simple feature fusion methods were tested to combine these three features. When applying a minimum rule based feature fusion method, the area under a receiving operating characteristic (ROC) curve is AUC=0.752, which is higher than the tumor size difference method based on RECIST guideline (AUC=0.689).

This preliminary study indicates that using the quantitative image features computed by the CAD scheme has the potential to improve the evaluation accuracy of patients' response to the chemotherapy in the future.

9414-125, Session PS7

Voxel-based registration of simulated and real patient CBCT data for accurate dental implant pose estimation

António H. Moreira, ICVS/3B's - PT Government Associate Lab. (Portugal) and School of Engineering, Univ. do Minho (Portugal) and DIGARC, Instituto Politécnico do Cávado e do Ave (Portugal); Sandro Queirós, School of Engineering, Univ. do Minho (Portugal) and ICVS/3B's - PT Government Associate Lab. (Portugal); Pedro Morais, ICVS/3B's - PT Government Associate Lab. (Portugal) and Univ. do Minho (Portugal); Nuno F. Rodrigues, DIGARC, Instituto Politécnico do Cávado e do Ave (Portugal) and Univ. of Minho (Portugal) and ICVS/3B's - PT Government Associate Lab. (Portugal); André Correia, Univ. do Porto (Portugal); Valter Fernandes, ICVS/3B's - PT Government Associate Lab. (Portugal); A. C. M. Pinho, Univ. do Minho (Portugal); Jaime C. Fonseca, School of Engineering, Univ. do Minho (Portugal); João L. Vilaça, DIGARC, Instituto Politécnico do Cávado e do Ave (Portugal) and ICVS/3B's - PT Government Associate Lab. (Portugal) and Univ. do Minho (Portugal)

Background: The success of manufactured dental implant-supported prosthesis is directly linked to the accuracy obtained during implant's pose estimation. Although traditional impression techniques and recent digital acquisition methods are acceptably accurate, a simultaneously fast, accurate and operator-independent methodology is still lacking.

Purpose: An image-based framework is proposed to estimate the patient-specific implant's pose using cone-beam computed tomography (CBCT) data and prior knowledge of implanted model.

Methods: The pose estimation is accomplished in a three-step approach: (1) a region-of-interest is extracted from the CBCT data using 2 operator-defined points at the implant's main axis; (2) a simulated CBCT volume of the known implanted model is generated through Feldkamp-Davis-Kress reconstruction and coarsely aligned to the defined axis; and (3) a voxel-based rigid registration is performed to optimally align both patient and simulated CBCT data, extracting the implant's pose from the optimal transformation.

Results: Three experiments were performed to evaluate the framework: (1) an in silico study using 48 implants distributed through 12 tridimensional synthetic mandibular models; (2) an in vitro study using an artificial mandible with 2 dental implants acquired with an i-CAT system; and (3) two clinical case studies. The results shown location errors of 67±34μm and 108μm, and angular misfits of 0.15±0.08º and 1.4º, for experiment 1 and 2, respectively. Visual assessment of clinical data results shown coherent alignment of the reference implant.

Conclusions: A novel image-based framework for implants' pose estimation from CBCT data was proposed, presenting accurate results in agreement with dental prosthesis modelling requirements.

9414-126, Session PS7

Automated classification of bone marrow cells in microscopic images for diagnosis of leukemia: a comparison of two classification schemes with respect to the segmentation quality

Sebastian Krappe, Michaela Benz, Thomas Wittenberg, Fraunhofer-Institut für Integrierte Schaltungen (IIS) (Germany); Torsten Haferlach, MLL Munich Leukemia Lab. (Germany); Christian Münzenmayer, Fraunhofer-Institut für Integrierte Schaltungen (IIS) (Germany)

The morphological analysis of bone marrow smears is fundamental for the diagnosis of leukemia. Currently, the counting and classification of the different types of bone marrow cells is done manually with the use of brightfield microscopy. This is a time consuming, partly subjective and tedious process. Furthermore repeated examinations of a slide yield intra- and inter-observer variances. For this reason an automation of morphological bone marrow analysis is pursued. This analysis comprises several steps: image acquisition and smear detection, cell localization and segmentation, feature extraction and cell classification. The automated classification of bone marrow cells is depending on the automated cell segmentation and the choice of adequate features extracted from different parts of the cell. In this work we focus on the evaluation of support vector machines (SVMs) and random forests (RFs) for the differentiation of bone marrow cells in 16 different classes, including immature and abnormal cell classes. Data sets of different segmentation quality are used to test the two approaches. Automated solutions for the morphological analysis for bone marrow smears could use such a classifier to pre-classify bone marrow cells and thereby shortening the examination duration.

9414-127, Session PS7

Standardized photographic documentation using low-cost consumer hardware and automatic calibration

Abin Jose, Daniel Haak, Stephan Jonas, Univ. Hospital Aachen (Germany); Vincent Brandenburg, RWTH Aachen Univ. (Germany); Thomas M. Deserno, Univ. Hospital Aachen (Germany)

Photographic documentation and image-based wound assessment is frequently performed in medical diagnostics, patient care, and clinical research. To support quantitative assessment, photographic imaging needs appropriate registration and calibration. Beside expensive and high-quality hardware, some methods involve color calibration using a reference pattern such as a standard color card. Then, the most challenging step is robust extraction of that pattern. In this paper, we adopt the lattice detection algorithm by Park et al. from real world imaging to medicine. At first, the algorithm extracts and groups feature points according to their geometric location. These groups are fed into a selection process, which is tested for suitability as a feature of a lattice grid. The group which describes the largest probability of the meshes of a lattice is selected and from it a template for an initial lattice cell is extracted. Then, a Markov random field (MRF) is modeled. Using the mean-shift belief propagation, the detection of the 2D lattice is solved iteratively as a spatial tracking problem. Supporting inexpensive consumer hardware such as smartphone-integrated cameras, a color plate is placed in the plane of the region of interest. Least-squares geometric calibration of projective distortions and non-linear color calibration in RGB space is supported by 35 corner points of 24 colored patches, respectively. The method is tested on 37 photographs in a rare disease registry of calciphylaxis, where non-standardized photographic documentation is collected nationwide from all contributing trial sites. At least, 31 lattice points were detected, outperforming the SIFT-based approach previously applied.

9414-128, Session PS7

Automatic anatomy partitioning of the torso region on CT images by using multiple organ localizations with a group-wise calibration technique

Xiangrong Zhou, Syoichi Morita, Gifu Univ. School of Medicine (Japan); Xinxin Zhou, Nagoya Bunri Univ. (Japan); Huayue Chen, Takeshi Hara, Ryujiro Yokoyama, Masayuki Kanematsu, Hiroaki Hoshi, Hiroshi Fujita, Gifu Univ. School of Medicine (Japan)

This paper describes an automatic approach for anatomy partitioning on 3D CT images that aims to divide the human torso region into a number of volume-of-interesting (VOI) according to the anatomical definition. The proposed approach combines a number of individual organ localization with a group-wise calibration and correction based on the detected organ locations to achieve an automatic and robust multiple organ localization task. The basic idea of proposed method is to detect the 3D minimum-bounding-box for each kind of organ on CT images individually based on local image textures and calibrate each detected box by using the global relationship of multiple organ locations. Machine-learning based template matching and a point-distribution-model based General Hough voting have been used in detection and calibration processes. We applied this approach for automatic partitioning of a torso region on CT images into 35 VOIs that present major organ regions required by routine diagnosis. The accuracy and usefulness of the proposed approach were shown in the experiment results from 4,000 3D torso CT scans.

9414-129, Session PS7

Automated torso organ segmentation from 3D CT images using structured perceptron and dual decomposition

Yukitaka Nimura, Yuichiro Hayashi, Nagoya Univ. (Japan); Takayuki Kitasaka, Aichi Institute of Technology (Japan); Kensaku Mori, Nagoya Univ. (Japan)

This paper presents a segmentation method for torso organs using structured perceptron and dual decomposition. A lot of methods have been proposed to enable automated extraction of organ regions from volumetric medical images. However, it is necessary to adjust empirical parameters of them to obtain precise organ regions. In this paper, we propose an organ segmentation method using structured output learning. Our method utilizes a graphical model and binary features which represent the relationship between voxel intensities and organ labels. Also we optimize the weights of the graphical model by structured perceptron and estimate the best organ label for a given image by dynamic programming and dual decomposition. The experimental result revealed that the proposed method can extract organ regions automatically using structured output learning. The error of organ label estimation was 4.6%. The DICE coefficients of right lung, left lung, liver, spleen, right kidney, and left kidney are 0.92, 0.89, 0.74, 0.67, 0.85, and 0.85, respectively.

9414-130, Session PS7

Automatic detection and segmentation of vascular structures in dermoscopy images using a novel vesselness measure based on pixel redness and tubularness

Pegah Kharazmi, The Univ. of British Columbia (Canada); Harvey Lui, University of British Columbia (Canada);

William Van Stoecker, Missouri University of Science and Technology (United States); Tim K. Lee, The Univ. of British Columia (Canada) and The BC Cancer Agency Research Ctr. (Canada)

Vascular structures are one of the most important features in the diagnosis and assessment of several skin disorders. The presence and clinical appearance of vascular structures in skin lesions is a discriminating factor among different skin diseases. In this paper, we address the problem of segmentation of vascular patterns in dermoscopy images. Our proposed method is composed of three parts. First, based on the biological properties of the human skin, we decompose the skin to melanin and hemoglobin component using independent component analysis of skin color images. We estimate the relative quantities and pure color densities of each component. Subsequently, we obtain three reference vectors of the mean RGB values of the normal skin, pigmented skin and blood vessels of the hemoglobin component by averaging over 100000 pixels of each group outlined by an expert. Based on the Euclidean distance thresholding, we generate a mask image that extracts the red regions of the skin. Finally, we apply the Frangi measure to the extracted red areas to segment the tubular structures and then apply the Otsu's thresholding to segment the vascular structures and get a binary vessel mask image. We have implemented the algorithm on a set of 50 dermoscopy images. In order to evaluate the performance of our method, we have artificially extended some of the existing vessels in 40 images of our dermoscopy data set and evaluated the performance of the algorithm to segment the newly added vessel pixels. We have tested the performance of the algorithm on this generated dataset and have obtained a sensitivity of 95% and specificity of 87%.

9414-131, Session PS7

Investigation of optimal feature value set in false positive reduction process for automated abdominal lymph node detection method

Yoshihiko Nakamura, Yukitaka Nimura, Nagoya Univ. (Japan); Takayuki Kitasaka, Shinji Mizuno, Aichi Institute of Technology (Japan); Kazuhiro Furukawa, Hidemi Goto, Michitaka Fujiwara, Nagoya Univ. Graduate School of Medicine (Japan); Kazunari Misawa, Aichi Cancer Ctr. Research Institute (Japan); Masaaki Ito, National Cancer Ctr. Hospital East (Japan); Shigeru Nawano, International Univ. of Health and Welfare (Japan); Kensaku Mori, Nagoya Univ. (Japan)

This paper presents an investigation of optimal feature value set in false positive reduction process for the automated method of enlarged abdominal lymph node detection. We have developed the automated abdominal lymph node detection method to aid for surgical planning. However, our previous method was not able to obtain the suitable feature value set. In this paper, we investigate the optimal feature value set in the false positive reduction process to improve the method for automated abdominal lymph node detection. By applying our improved method to 28 cases of abdominal 3D CT images, we detected about 74.7% of the abdominal lymph nodes with 11.8 FPs/case.

9414-132, Session PS7

A pilot study on bladder wall thickness at different filling stages

Xi Zhang, Yang Liu, Baojuan Li, Guopeng Zhang, Fourth Military Medical Univ. (China); Zhengrong Liang, State Univ. of New York at Stony Brook (United States); Hongbing Lu, Fourth Military Medical Univ. (China)

The ever-growing death rate and the high recurrence of bladder cancer make the way of early detection and appropriate follow-up procedure of bladder cancer attract more attention. Recent studies show that bladder wall thickness tends to be a good indicator for detecting bladder wall abnormalities. However, it is difficult to quantitatively compare the bladder thickness of the same subject at different filling stages or among different subjects. In order to eliminate individual difference and correct thickness value influenced by different bladder filling stages, we preliminary reveal the relationship between bladder wall thickness and bladder volume based on a pipeline for thickness measurement and analysis we proposed in our previous work. In this study, we acquired 5 series, 20 cases of MRI sequence of bladder with different filling stage from 5 subjects. Pearson correlation analysis was applied to confirm that negative correlation with a coefficient -0.5057 exists between two variables. Unary linear regression result shown that the regression is significant (p=0.0229). These conclusions can use to correct the difference of wall thickness. Thickness feature after correcting will be more effective for indicating the bladder wall abnormalities.

Conference 9415: Image-Guided Procedures, Robotic Interventions, and Modeling

Sunday - Tuesday 22–24 February 2015

Part of Proceedings of SPIE Vol. 9415 Medical Imaging 2015: Image-Guided Procedures, Robotic Interventions, and Modeling

9415-1, Session 1

Integration of a biomechanical simulation for mitral valve reconstruction into a knowledge-based surgery assistance system

Nicolai J. Schoch, Ruprecht-Karls-Univ. Heidelberg (Germany); Sandy Engelhardt, Deutsches Krebsforschungszentrum (Germany); Norbert Zimmermann, UniversitätsKlinikum Heidelberg (Germany); Stefanie Speidel, Karlsruher Institut für Technologie (Germany); Raffaele De Simone, UniversitätsKlinikum Heidelberg (Germany); Ivo Wolf, Fachhochschule Mannheim (Germany) and Deutsches Krebsforschungszentrum (Germany); Vincent Heuveline, Ruprecht-Karls-Univ. Heidelberg (Germany)

A mitral valve reconstruction (MVR) is a complex operation in which the functionality of incompetent mitral valves is re-established by applying surgical techniques. This work deals with the biomechanical simulation of operation scenarios for an MVR, and the simulation's integration into a knowledge-based surgery assistance system.

We present an adequate framework for the definition of the corresponding surgical workflow, which combines semantically stored surgical expert knowledge with a biomechanical simulation. 'Surgical rules' which represent decision and assessment criteria for surgical decision-making are being represented ontologically in a knowledge base. Through case-based reasoning these 'rules' can then be applied on patient-specific data, in order to be converted into boundary conditions for the biomechanical soft tissue simulation which is based on the Finite Elements Method (FEM). The simulation, which is implemented in the C++ FEM software HiFlow3, is controlled and activated via the Medical Simulation Markup Language (MSML), and makes use of High Performance Computing (HPC) methods to cope with real-time requirements in surgery. The simulation results are analyzed by surgeons regarding the quality of the virtual reconstruction and the consequential remedial effects on the mitral valve and on its functionality. The whole setup has the potential to support the intraoperative decision-making process during MVR where the surgeon usually has to make fundamental decision under time pressure.

9415-2, Session 1

A dynamic heart phantom with functional mitral and aortic valves

Claire Vannelli, John T. Moore, Jonathan McLeod, Dennis A. Ceh, Terry M. Peters, Robarts Research Institute (Canada)

Cardiac valvular stenosis, prolapse and regurgitation are increasingly common conditions, particularly in an elderly population with limited potential for on-pump cardiac surgery. NeoChord©, MitraClip© and numerous stent-based transcatheter aortic valve implantation (TAVI) devices provide an alternative to intrusive cardiac operations; performed while the heart is beating, these procedures necessitate that surgeons and cardiologists learn new image-guidance based techniques. Developing these visual aids is a challenging task that benefits from sophisticated simulators. Several phantoms are already available, such as UL's dynamic four-chamber heart, and the MR-compatible system from Shelley Medical. However, previous models lack features needed to simulate off-pump valvular

procedures: functional, dynamic valves, apical and vascular access, and user flexibility for different activation patterns such as variable heart rates and rapid pacing. We present a left ventricle phantom with these characteristics. The phantom can be used to simulate valvular repair and replacement procedures with magnetic tracking, augmented reality, fluoroscopy and ultrasound guidance. This tool serves as a platform to develop image-guidance and image processing techniques required for minimally invasive cardiac interventions. The phantom mimics in vivo mitral and aortic valve motion with ultrasound and has a measured left ventricular ejection fraction of 51%. Given its realistic imaging properties and non-biodegradable composition—silicone for tissue, water for blood—the system promises to reduce the number of animal trials required to develop image guidance applications for valvular repair and replacement. The phantom has been used in validation studies for both TAVI image-guidance techniques, and image-based mitral valve tracking algorithms.

9415-3, Session 1

Beating heart mitral valve repair with integrated ultrasound imaging

A. Jonathan McLeod, John T. Moore, Terry M. Peters, Robarts Research Institute (Canada)

Beating heart valve therapies rely extensively on image guidance to treat patients inoperable for conventional surgery. Mitral valve repair techniques including the MitrClip, NeoChord, and emerging transcatheter mitral valve replacement techniques all rely primarily on transesophageal echocardiography for guidance. These images are often difficult to interpret as the tool will cause shadowing artifacts that occlude tissue near the targeting site. Here, we integrate ultrasound imaging directly into the NeoChord device. This provides an unobstructed imaging plane that can visualize the valve leaflets as they are engaged by the device and can aid in achieving both a proper bite and spacing between the neochordae implants. A user study in a phantom environment is performed to validate this device.

9415-4, Session 1

Endocardial left ventricle feature tracking and reconstruction from tri-plane TEE data for computer-assisted image guidance and cardiac function assessment

Shusil Dangi, Yehuda K. Ben-Zikri, Rochester Institute of Technology (United States); Karl Q. Schwarz, Univ. of Rochester Medical Ctr. (United States) and Rochester Institute of Technology (United States); Nathan Cahill, Cristian A. Linte, Rochester Institute of Technology (United States)

While 2D US has been the clinical standard for over two decades for monitoring and assessing cardiac function, as well as providing support via intra-operative visualization and guidance for minimally invasive cardiac interventions, developments in 3D image acquisition and transducer design and technology have revolutionized echocardiography imaging, enabling both real-time 3D trans-esophageal and intra-cardiac image acquisition. However, in most cases the clinicians do not access the entire 3D image volume when analyzing the data, but rather focus on several key views that render the cardiac anatomy of interest during the US imaging exam, enabling image acquisition at a much higher spatial and temporal

resolution. Two such common approaches are the bi-plane and tri-plane data acquisition protocols; as their name states, the former comprises two orthogonal image views, while depicts the cardiac anatomy based on three co-axially intersecting views spaced at 60° to one another. Since cardiac anatomy is continuously changing, the intra-operative anatomy depicted using real-time US imaging also needs to be updated by tracking the key features of interest and endocardial LV boundaries. Therefore, near real-time feature tracking in US images is critical for two reasons: 1) to identify location of surgical targets for accurate tool to target navigation and on-target instrument positioning; and 2) to enable pre- to intra-op image registration as a means to fuse pre-op CT or MR images used during planning with intra-operative images for enhanced guidance. In this paper we describe several techniques that consist of the pre- processing of the acquired multi-plane time series US images using region of interest identification and monogenic filtering, demonstrate real-time tracking of the LV endocardial features from real-time tri-plane 3D TEE time series images, reconstruct the endocardial LV geometry using the tri-plane contours and spline interpolation, and assess the accuracy of the proposed workflow against gold-standard results from the GE Echopac PC clinical software according to quantitative clinical left ventricle characterization parameters, such as the length, circumference, area and volume computed via both method of discs and the length-area method. Our proposed workflow leads to consistent identification of the left ventricle endocardium, with minimal user interaction and manuality, and operating in near real-time suitable for intra-operative applications and ``on-the-fly'' computer-assisted assessment of ejection fraction for cardiac function monitoring.

9415-5, Session 1

The effect of elastic modulus on ablation catheter contact area

Jon J. Camp, Mayo Clinic (United States); Cristian A. Linte, Rochester Institute of Technology (United States); Maryam E. Rettmann, Deyu Sun, Douglas L. Packer, Mayo Clinic (United States); Richard A. Robb, Mayo Clinic College of Medicine (United States); David R. Holmes III, Mayo Clinic (United States)

Cardiac ablation consists of navigating a catheter into the heart and delivering RF energy to electrically isolate tissue regions that generate or propagate arrhythmia. There is limited information available intra-operatively regarding intricate electrode-tissue contact, which directly impacts the quality of produced lesions. Recent advances in ablation catheter design provide intra-procedural estimates of tissue-catheter contact force, but the most direct indicator of lesion quality for any particular energy level and duration is the tissue-catheter contact area, and that is a function of not only force, but catheter pose and material elasticity as well.

In this experiment, we have employed real-time ultrasound (US) imaging to determine the complete interaction between the ablation electrode and tissue to accurately estimate contact, which will help to better understand the effect of catheter pose and position relative to the tissue. By simultaneously recording tracked position, force reading and US image of the ablation catheter, the differing material properties of polyvinyl alcohol cryogel phantoms are shown to produce varying amounts of tissue depression and contact area (implying varying lesion quality) for equivalent force readings. We have shown that the elastic modulus significantly affects the surface-contact area between the catheter and tissue at any level of contact force. Thus we provide evidence that a prescribed level of catheter force may not always provide sufficient contact area to produce an effective ablation lesion in the prescribed ablation time.

9415-96, Session 1

In memoriam Ferenc Jolesz

Gabor Fichtinger, Queen's Univ. (Canada)

Ferenc Jolesz passed away unexpectedly on the last day of 2014. We remember him as one of the fathers of Image Guided Procedures; the visionary force behind a number of ground breaking inventions, such as the double-donut open MRI scanner and MRI-guided Focused Ultrasound (MRgFUS) therapy. He was a mentor for generations of researchers in the nascent field of image-guided therapy, a fearless intellectual and a revolutionary scientist.

9415-6, Session 2

Multimodal system for the planning and guidance of bronchoscopy

William E. Higgins, Ronnarit Cheirsilp, Xiaonan Zang, Patrick D. Byrnes, The Pennsylvania State Univ. (United States)

Many technical innovations in multimodal radiologic imaging and bronchoscopy have emerged recently in the effort against lung cancer. Modern X-ray computed-tomography (CT) scanners provide three-dimensional (3D) high-resolution chest images, positron emission tomography (PET) scanners give complementary molecular-imaging data, and new integrated PET/CT scanners combine the strengths of both modalities. State-of-the-art bronchoscopes permit minimally invasive tissue sampling, with vivid endobronchial video enabling navigation deep into the airwaytree periphery, while complementary endobronchial ultrasound (EBUS) reveals local views of anatomical structures outside the airways. In addition, image-guided intervention (IGI) systems have proven their utility for CT-based planning and guidance of bronchoscopy. Unfortunately, no IGI system exists that integrates all sources effectively through the complete lung-cancer staging work flow. This paper presents a prototype of a computer-based multimodal IGI system that strives to fill this need. The system combines a wide range of automatic and semi-automatic image processing tools for multimodal data fusion and procedure planning. It also provides a flexible graphical user interface for follow-on guidance of bronchoscopy/EBUS. Human-study results demonstrate the system's potential.

9415-7, Session 2

Accuracy validation of an image guided laparoscopy system for liver resection

Stephen A. Thompson, Johannes Totz, Yi Song, Univ. College London (United Kingdom); Stian Johnsen, University College London (United Kingdom); Danail Stoyanov, Sébastien Ourselin, Univ. College London (United Kingdom); Kurinchi Gurusamy, Crispin Scheider, Brian Davidson, Division of Surgery and Interventional Science, UCL (United Kingdom); David Hawkes, Matthew Clarkson, Univ. College London (United Kingdom)

We present an analysis of the registration component of a proposed image guidance system for image guided liver surgery. The analysis is performed on a visually realistic liver phantom and in-vivo porcine data. A robust registration process that can be deployed clinically is a key component of any image guided surgery system. It is also essential that the accuracy of the registration can be quantified and communicated to the surgeon. We summarize our proposed guidance system and our experience of deploying it. The registration component combines an intuitive manual alignment stage, surface reconstruction from a tracked stereo laparoscope and a rigid iterative closest point registration. Testing of the system on a liver phantom shows that subsurface landmarks can be localised to an accuracy of 2.9 mm RMS. Testing on porcine liver models demonstrated that registration can be performed during surgery, with an error of less than 10 mm RMS for surface landmarks.

9415-8, Session 2

Rendering-based video-CT registration with physical constraints for image-guided endoscopic sinus surgery

Yoshito Otake, Nara Institute of Science and Technology (Japan); Simon Leonard, Austin Reiter, Purnima Rajan, Jeffrey H. Siewerdsen, Masaru Ishii, Russell H. Taylor, Gregory D. Hager, Johns Hopkins Univ. (United States)

We present a system for registering the coordinate frame of an endoscope to pre- or intra- operatively acquired CT data based on optimization of the similarity metric between an endoscopic image and an image predicted via rendering of CT. Our method is robust and semi-automatic because it takes account of physical constraints, specifically, collisions between the endoscope and the anatomy, to initialize and constrain the optimization search. The proposed optimization method is based on a stochastic algorithm, Covariance Matrix Adaptation Evolutionary Strategy (CMA-ES), which evaluates a large number of similarity metric functions in parallel on a graphics processing unit. The set of endoscope poses that are feasible during the surgery (i.e., the poses which does not yield collision with surrounding anatomy) was estimated a priori based on the patient-specific anatomical structure in CT data. The collision free poses were clustered into n clusters and the centroid of each cluster was used as initialization points, thus it eliminates manual initialization process. The collision detection was also used in the stochastic optimization to reject an infeasible sample point. Images from a cadaver and a patient were used for evaluation. The registration error was 0.83 mm and 1.97 mm for cadaver and patient images respectively. The average registration time for 60 endoscopic images was 4.4 seconds. The patient study demonstrated robustness of the proposed algorithm against a moderate anatomical deformation.

9415-9, Session 2

Image-based tracking of the suturing needle during laparoscopic interventions

Stefanie Speidel, Andrea Kroehnert, Sebastian Bodenstedt, Karlsruher Institut für Technologie (Germany); Hannes Kenngott, Beat Peter Müller-Stich, UniversitätsKlinikum Heidelberg (Germany); Rüdiger Dillmann, Karlsruher Institut für Technologie (Germany)

One of the most complex and difficult tasks for surgeons during minimally invasive interventions is suturing. A prerequisite to assist the suturing process is the tracking of the needle. The endoscopic images provide a rich source of information which can be used for needle tracking. In this paper, we present an image-based method for markerless needle tracking. The method uses a color-based and geometry-based segmentation to detect the needle. Once an initial needle detection is obtained, a region of interest enclosing the extracted needle contour is passed on to a reduced segmentation. It is evaluated with in vivo images from da Vinci interventions.

9415-10, Session 2

Toward real-time endoscopically-guided robotic navigation based on a 3D virtual surgical field model

Yuanzheng Gong, Danying Hu, Blake Hannaford, Eric J. Seibel, Univ. of Washington (United States)

The challenge is to accurately guide the surgical tool within the three-dimensional (3D) surgical field for robotically-assisted operations such as tumor margin removal from a debulked brain tumor cavity. The proposed technique is 3D image-guided surgical navigation based on matching intraoperative video frames to a 3D virtual model of the surgical field. A small (1.6-mm diameter) laser-scanning endoscopic camera was attached to a mock minimally-invasive surgical tool that was manipulated toward a region of interest (residual tumor) within a phantom of a debulked brain tumor. Video frames from the endoscope provided features that were matched to the 3D virtual model, which were recorded earlier by raster scanning over the surgical field. Camera pose (position and orientation) is recovered by implementing a constrained bundle adjustment algorithm. Navigational error during the approach to fluorescence target (residual tumor) is determined by comparing the calculated camera pose to the measured camera pose using a micro-positioning stage. From these preliminary results, computation efficiency of the algorithm in Matlab code is near real-time (2.5 sec for each estimation of pose). The computation efficiency can be improved by implementation in C++. Error analysis produced 3 mm distance error and 2.5 degree of orientation error on average. The sources of these errors come from 1) inaccuracy of the 3D virtual model, generated on a calibrated RAVEN robotic platform with stereo tracking; 2) inaccuracy of endoscope intrinsic parameters, such as focal length; and 3) any endoscopic image distortion from scanning irregularities. This work demonstrates feasibility of micro-camera 3D guidance of a robotic surgical tool.

9415-11, Session 2

Electrical impedance map (EIM) for margin assessment during robot-assisted laparoscopic prostatectomy (RALP) using a microendoscopic probe

Aditya Mahara, Shadab Khan, Thayer School of Engineering at Dartmouth (United States); Alan R. Schned, Elias S. Hyams, Dartmouth Hitchcock Medical Ctr. (United States); Ryan J. Halter, Thayer School of Engineering at Dartmouth (United States)

Background: Positive surgical margins (PSMs) found following prostate cancer surgery are a significant risk factor for post-operative disease recurrence. Noxious adjuvant radiation and chemical-based therapies are typically offered to men with PSMs. Unfortunately, no real-time intraoperative technology is currently available to guide surgeons to regions of suspicion during the initial prostatectomy where immediate surgical excisions could be used to reduce the chance of PSMs. Purpose: A microendoscopic electrical impedance sensing probe was developed with the intention of providing real-time feedback regarding margin status to surgeons during robot-assisted laparoscopic prostatectomy (RALP) procedures. Methods: A radially configured 17-electrode microendoscopic probe was designed, constructed, and initially evaluated through use of gelatin-based phantoms and ex vivo human prostate specimens. Impedance measurements are recorded at 10 kHz using a high-speed FPGA-based electrical impedance tomography (EIT) system. Tetrapolar impedances are recorded from a number of different electrode configurations strategically chosen to sense tissue in a pre-defined sector underlying the probe face. A circular electrical impedance map (EIM) with several color-coded pie-shaped sectors is created to represent the impedance values of the probed tissue. Results: Gelatin phantom experiments show an obvious distinction in the impedance maps between high and low conductivity regions. Similarly, the EIM generated from the ex vivo prostate case shows distinguishing features between cancerous and benign regions. Based on successful development of this probe and these promising initial results, EIMs of additional prostate specimens are being collected to further evaluate this approach for intraoperative surgical margin assessment during RALP procedures.

9415-12, Session 3

Thalamic nuclei segmentation in clinical 3T T1-weighted Images using high-resolution 7T shape models

Yuan Liu, Pierre-François D'Haese, Benoit M. Dawant, Vanderbilt Univ. (United States)

Accurate and reliable identification of thalamic nuclei is important for surgical interventions and neuroanatomical studies. This is a challenging task due to their small sizes and low intra-thalamic contrast in standard T1-weighted or T2-weighted images. Previously proposed techniques rely on diffusion imaging or functional imaging. These require additional scanning and are limited by the low resolution and signal-to-noise ratio in these images. In this paper, we aim to directly segment the thalamic nuclei in standard 3T T1-weighted images using shape models. We manually delineate the structures in high-field MR images and build high resolution shape models from a group of subjects. We then investigate if the nuclei locations can be inferred from the whole thalamus. To do this, we hierarchically fit joint models. We start from the entire thalamus and fit a model that captures the relation between the thalamus and large nuclei groups. This allows us to infer the boundaries of these nuclei groups and we repeat the process until all nuclei are segmented. We validate our method using one subject by comparing our results on a 3T image to the manual contours drawn on the corresponding 7T images. Results we have obtained (dice coefficients ranging from 0.50 to 0.87 and mean surface errors from 0.33mm to 1.19mm) suggest the feasibility of using such joint shape models to localize the thalamic nuclei. This may have a direct impact on surgeries such as Deep Brain Stimulation procedures that require the implantation of stimulating electrodes in specific thalamic nuclei.

9415-13, Session 3

Three-dimensional curvilinear device reconstruction from two fluoroscopic views

Charlotte Delmas, GE Healthcare France (France) and LORIA (France); Marie-Odile Berger, Erwan Kerrien, INRIA (France) and LORIA (France); Cyril Riddell, Yves L. Trousset, GE Healthcare France (France); René Anxionnat, Serge Bracard, CHU, Hôpital Neurologique (France)

In interventional radiology, navigating devices under the sole guidance of fluoroscopic images inside a complex architecture of tortuous and narrow vessels like the cerebral vascular tree is a difficult task. Visualizing the device in 3D could facilitate this navigation. For curvilinear devices such as guide-wires and catheters, a 3D reconstruction may be achieved by using two simultaneous fluoroscopic views, as available on a biplane acquisition system. The purpose of this paper is to present a new automatic three-dimensional curve reconstruction method that has the potential to reconstruct complex 3D curves and does not require a perfect segmentation of the endovascular device. Using epipolar geometry, our algorithm translates the point correspondence problem into a segment correspondence problem. Potential 3D curves can be formed and evaluated independently after identifying all possible combinations of compatible 3D segments. Correspondence is then inherently solved by looking in 3D space for the most coherent curve in terms of continuity and curvature. This problem can be cast into a graph problem where the most coherent curve corresponds to a shortest path in the graph. We present quantitative results of curve reconstructions performed from numerically simulated projections of complex 3D curves extracted from cerebral vascular trees affected with brain arteriovenous malformations as well as fluoroscopic image pairs of a guide-wire introduced inside a cerebral vascular phantom. Our method was able to select the correct 3D segments in 96.5% of simulated cases thus demonstrating its ability to handle complex 3D curves and can deal with imperfect 2D segmentation.

9415-14, Session 3

Localizing and tracking electrodes using stereovision in epilepsy cases

Xiaoyao Fan, Songbai Ji, Dartmouth College (United States); David W. Roberts, Dartmouth Hitchcock Medical Ctr. (United States) and Dartmouth College (United States); Keith D. Paulsen, Dartmouth College (United States)

In epilepsy cases, subdural electrodes are often implanted to acquire intracranial EEG (iEEG) for seizure localization and resection planning. However, the electrodes may shift significantly between implantation and resection, during the time that the patient is monitored for iEEG recording. As a result, the accuracy of surgical planning based on electrode positions at the time of resection can be compromised. Previous studies have only quantified the electrode shift with respect to the skull, but not with respect to the cortical surface, because tracking cortical shift between surgeries is challenging. In this study, we use stereovision to visualize the cortical surface as well as electrodes, record 3D positions of the electrodes in MR space at the time of implantation and resection, respectively, and quantify the raw displacements, i.e., with respect to the skull. Furthermore, we track the cortical surface and quantify the shift between surgeries using an optical flow-based algorithm. Finally, we compute the electrode shift with respect to the cortical surface by subtracting the cortical shift from raw measured displacements. We illustrate the method using one patient example. The results show that the electrodes not only shifted significantly with respect to the skull (7.98 ± 1.24 mm in lateral direction), but also with respect to the cortical surface (9.14 ± 4.45 mm), whereas the cortical surface did not shift significantly in the lateral direction between surgeries (2.83 ± 1.23 mm).

9415-15, Session 3

Real-time surgery simulation of intracranial aneurysm clipping with patient-specific geometries and haptic feedback

Wolfgang Fenz, Johannes Dirnberger, RISC Software GmbH (Austria)

Providing suitable training for aspiring neurosurgeons is becoming more and more problematic. The increasing popularity of the endovascular treatment of intracranial aneurysms leads to a lack of simple surgical situations for clipping operations, leaving mainly the complex cases, which present even experienced surgeons with a challenge. To alleviate this situation, we have developed a training simulator with haptic interaction allowing trainees to practice virtual clipping surgeries on real patient-specific vessel geometries. By using specialized FEM algorithms (Fast Finite Element method, matrix condensation) combined with GPU acceleration, we achieve the necessary frame rate for smooth real-time interaction with the detailed models that are needed for a realistic simulation of the vessel wall deformation caused by the clamping with surgical clips. Vessel wall geometries for typical training scenarios are obtained from 3D-reconstructed medical image data, while for the instruments (clipping forceps, various types of clips, suction tubes) we use models provided by manufacturer Aesculap AG. Collisions between vessel and instruments have to be continuously detected and transformed into corresponding boundary conditions and feedback forces, which is calculated using a contact plane method. After a training, the achieved result can be assessed based on various criteria, including a simulation of the residual blood flow into the aneurysm. The addition of rigid models for the surgical access through the skull and brain tissue, and the coupling of a real forceps to the haptic input device further increase the realism of the system.

9415-16, Session 3

Application and histology-driven refinement of active contour models to functional region and nerve delineation: towards a digital brainstem atlas

Sharmin Sultana, Michel A. Audette, Nirmal Patel, Old Dominion Univ. (United States)

This paper presents digital formatting of a printed atlas of the brainstem and the delineation of cranial nerves from this digital atlas. It also describes on-going work on the 3D resampling and refinement of the 2D functional regions and nerve contours. In MRI-based anatomical modeling for neurosurgery planning and simulation, the complexity of the functional anatomy entails a digital atlas approach, rather than less descriptive voxel or surface-based approaches. However, there is an insufficiency of descriptive digital atlases, in particular of the brainstem. Our approach proceeds from a series of numbered, contour-based sketches coinciding with slices of the brainstem featuring both closed and open contours. The closed contours coincide with functionally relevant regions, in which case our objective is to fill in each corresponding label, which is analogous to painting numbered regions in a paint-by-numbers kit. The open contours typically coincide with cranial nerves. This 2D phase is needed in order to produce densely labeled regions that can be stacked to produce 3D regions, as well as identifying embedded paths and outer attachment points of cranial nerves. Cranial nerves are modeled using an explicit contour based technique called 1-simplex. The relevance of cranial nerves modeling of this project is two-fold: i) this atlas will fill a void left by the brain segmentation communities, as no digital atlas of the brainstem exist, and ii) this atlas is necessary to make explicit the attachment points of major nerves (except I and II) having cranial origin, specifically nerves X and XI.

9415-17, Session 4

Comparison of tablet-based strategies for incision planning in laser microsurgery

Andreas Schoob, Stefan Lekon, Dennis Kundrat, Lüder A. Kahrs, Leibniz Univ. Hannover (Germany); Leonardo S. Mattos, Istituto Italiano di Tecnologia (Italy); Tobias Ortmaier, Leibniz Univ. Hannover (Germany)

Recent research has revealed that incision planning in laser surgery deploying stylus and tablet outperforms state-of-the-art micro-manipulator-based laser control. Providing more detailed quantitation regarding this approach, this paper presents a comparative study of six tablet-based strategies for laser path planning. Reference strategy is defined by monoscopic visualization and continuous path drawing on a graphics tablet. Further concepts deploying stereoscopic or a synthesized laser view, point-based path definition, real-time teleoperation or a pen display are compared with the reference scenario. Volunteers were asked to redraw and ablate stamped lines on a sample. Performance is assessed by measuring planning accuracy, completion time and ease of use. Results demonstrate that significant differences exist between proposed concepts. The reference strategy provides more accurate and intuitive incision planning than the stereo or laser view scenario. Real-time teleoperation performs best with respect to completion time without indicating any significant deviation in accuracy and usability. Point-based planning as well as the pen display provide most accurate planning and increased ease of use compared to the reference strategy. As a result, combining the pen display approach with point-based planning has potential to become a powerful planning strategy because of benefiting from improved hand-eye-coordination on the one hand and from a simple but accurate technique for path definition on the other hand. These findings as well as the overall usability scale indicating high acceptance and consistence of proposed strategies motivate further advanced tablet-based planning in laser microsurgery.

9415-18, Session 4

Automatic electrode configuration selection for image-guided cochlear implant programming

Yiyuan Zhao, Benoit M. Dawant, Jack H. Noble, Vanderbilt Univ. (United States)

Cochlear implants (CIs) are neural prosthetics that stimulate the auditory nerve pathways within the cochlea using an implanted electrode array to restore hearing. After implantation, the CI is programmed by an audiologist who determines which electrodes are active, i.e., the electrode configuration, and selects other stimulation settings. Recent clinical studies by our group have shown that hearing outcomes can be significantly improved by using an image-guided electrode configuration selection technique we have designed. Our goal in this work is to automate the electrode configuration selection step with the long term goal of developing a fully automatic system that can be translated to the clinic. Until now, the electrode configuration selection step has been performed by an expert with the assistance of image analysis-based estimates of the electrode-neural interface. To automatically determine electrode configuration, we have designed an optimization approach and propose the use of a cost function with feature terms designed to interpret the image analysis data in a similar fashion as the expert. Further, we have designed an approach to select parameters in the cost function using our database of existing electrode configuration plans as training data. The results we present show that our automatic approach results in electrode configurations that are better or equally as good as manually selected configurations in over 80% of the cases tested. This method represents a crucial step towards clinical translation of our image-guided cochlear implant programming system.

9415-19, Session 4

Nonholonomic catheter path reconstruction using electromagnetic tracking

Elodie Lugez, Hossein Sadjadi, Selim G. Akl, Gabor Fichtinger, Queen's Univ. (Canada)

PURPOSE: Catheter path reconstruction is a necessary step in many interventional procedures, such as cardiovascular interventions and high-dose-rate brachytherapy. To overcome shortcomings in standard imaging modalities, electromagnetic tracking has been employed to reconstruct catheter paths. However, tracking error still poses a challenge in accurate path reconstruction. We address this challenge by means of a filtering technique incorporating nonholonomic motion constraints of the sensor embedded in the catheter.

METHODS: The nonholonomic motion model of the sensor and the measurement data were integrated with an extended Kalman filter (EKF). The performance of our proposed approach was experimentally evaluated using an Ascension trakSTAR electromagnetic tracker. Sensor measurements were recorded during insertions of an electromagnetic sensor (model 55) along predefined ground truth path. The filter was implemented in MATLAB and applied to measurement data. The filter's performance was compared to raw measurements and filters provided by the manufacturer.

RESULTS: The root-mean-square (RMS) error along the path was 5.8 mm for the raw measurements and 2.4 mm with manufacturer's filters. Using our filter uniting EKF with the nonholonomic motion model, the RMS error was reduced to 1.6 mm.

CONCLUSION: Compared to other filtering methods, our approach successfully improved the path reconstruction accuracy by exploiting the orientation measurements, in addition to the position measurements. Our filtering seems promising for a variety of clinical procedures involving reconstruction of a catheter path.

9415-20, Session 4

Methods for intraoperative, sterile pose-setting of patient-specific microstereotactic frames

Benjamin Vollmann, Samuel Müller, Dennis Kundrat, Tobias Ortmaier, Lüder A. Kahrs, Leibniz Univ. Hannover (Germany)

This work proposes new methods for a microstereotactic frame based on bone cement fixation. Microstereotactic frames are under investigation for minimal invasive temporal bone surgery, e.g. cochlear implantation, or for deep brain stimulation, where products are already on the market. The correct pose of the microstereotactic frame can either be adjusted outside or inside the operating room and used for e.g. drill or electrode guidance. We present a patient-specific, disposable frame that allows intraoperative, sterile pose-setting. Key idea of our approach is bone cement between two plates that cures while the plates are positioned with a mechatronics system in the desired pose. This paper includes new designs of microstereotactic frames, a system for alignment and first measurements to analyze accuracy and applicable load.

9415-21, Session 4

Robot-assisted, ultrasound-guided minimally invasive navigation tool for brachytherapy and ablation therapy - initial assessment

Srikanth Bhattad, Abelardo Escoto, Canadian Surgical Technologies and Advanced Robotics (Canada); Richard Malthaner, Canadian Surgical Technologies and Advanced Robotics (Canada) and Univ. of Western Ontario (Canada); Rajni Patel, Canadian Surgical Technologies and Advanced Robotics (Canada) and Western Univ. (Canada)

Brachytherapy and thermal ablation are relatively new approaches in minimally invasive interventions for treating malignant tumors. Ultrasound remains the most favored choice for imaging feedback, the benefits being cost effectiveness, non-ionizing radiation (safer to use), and easy access in an OR. However it does not generally provide high contrast and noise free images as compared to other imaging modalities. Image distortion occurs when the sound waves pass though a medium that contains air (for instance lung) and/or when the target organ being imaged is deep within the body. The distorted images make it quite difficult to recognize and localize tumors and surgical tools. Often tools such as a bevel-tipped needle, deflect from its path during insertion. A single perspective view then makes it difficult to detect the needle tip. The shifting of the target due to cardiac and/or respiratory motion can add further errors in reaching the target.

This paper describes a comprehensive system that uses robot dexterity to capture 2D ultrasound images in various pre-determined modes for generating 3D ultrasound images and assists in maneuvering a surgical tool. An interactive 3D virtual reality environment is developed that visualizes various artifacts present in the surgical site. Custom methods and tools are implemented that guide the clinician during needle maneuvering and target attainment. An ablation tool that visualizes the changes during the complete ablation process and evaluates it in its entirety is integrated. A phantom test-bed is fabricated to imitate the contra-lateral lung motion and cardiac motion for ex-vivo lung experiments. A tele-operation mode and a semi-autonomous mode for performing various surgical tasks are implemented.

The experimental results show successful needle-tip detection in collapsed lung and liver. A mean accuracy of 0.93 mm for ex-vivo without motion and 1.36 mm for ex-vivo with motion was obtained for brachytherapy seed injection. In-vivo porcine lung brachytherapy was performed with an accuracy of 1.3 mm in target attainment. The system provides improved needle maneuvering, navigation and tumor localization. It represents the

surgical site more realistically, reduces tissue trauma and demonstrates the potential for application in real clinical scenarios for different organs.

9415-22, Session 4

Generating patient-specific pulmonary vascular models for surgical planning

Daniel Murff, Univ. of Florida (United States); Jennifer Co-Vu, Univ of Florida (United States); Walter G. O'Dell, Univ. of Florida (United States)

Each year in the U.S., 7.4 million surgical procedures involving the major vessels are performed. Many of our patients require multiple surgeries, and many of the procedures include "surgical exploration". Procedures of this kind come with a significant amount of risk, carrying up to a 17.4% predicted mortality rate. This is especially concerning for our target population of pediatric patients with congenital abnormalities of the heart and major pulmonary vessels. This paper offers a novel approach to surgical planning which includes studying virtual and physical models of pulmonary vasculature of an individual patient before operation obtained from conventional 3D X-ray computed tomography (CT) scans of the chest. These models would provide clinicians with a non-invasive, intricately detailed representation of patient anatomy, and could reduce the need for invasive planning procedures such as exploratory surgery. Researchers involved in the AirPROM project have already demonstrated the utility of virtual and physical models in treatment planning of the airways of the chest. Clinicians have acknowledged the potential benefit from such a technology. A method for creating patient-derived physical models is demonstrated on pulmonary vasculature extracted from a CT scan with contrast of an adult human. Using a modified version of the NIH ImageJ program, a series of image-processing functions are used to extract and mathematically reconstruct the vasculature tree structures of interest. An auto-generated STL file is sent to a 3D printer to create a physical model of the major pulmonary vasculature generated from 3D CT scans of patients.

9415-23, Session 5

Scaphoid fracture fixation: localization of bones through statistical model to ultrasound registration

Emran Mohammad Abu Anas, Abtin Rasoulian, The Univ. of British Columbia (Canada); Paul St. John, David R. Pichora, Kingston General Hospital (Canada); Parvin Mousavi, Queen's Univ. (Canada); Victoria A. Lessoway, BC Women's Hospital and Health Ctr. (Canada); Alexander Seitel, The Univ. of British Columbia (Canada); Ilker Hacihaliloglu, Rutgers, The State Univ. of New Jersey (United States); Robert N. Rohling, Purang Abolmaesumi, The Univ. of British Columbia (Canada)

Percutaneous treatment of scaphoid fractures has found increasing interest in recent years as it promises to minimize soft-tissue damage, and minimizes the risk of infections and the loss of the joint stability. However, as this procedure is mostly performed on 2D fluoroscopic images, the accurate localization of the scaphoid bone for fracture fixation renders extremely challenging. In this work, we thus propose the integration of a statistical wrist model with 3D intraoperative ultrasound for accurate localization of the scaphoid bone. We utilize a previously developed statistical wrist model and register it to bone surfaces in ultrasound images using a probabilistic approach that involves expectation-maximization. We utilize local phase symmetry to detect features in noisy ultrasound images; in addition, we use shadow information in ultrasound images to enhance and set apart bone from other features. Feasibility experiments are performed by registering the wrist model to 3D ultrasound volumes of two different wrists at two different wrist positions. And the result indicates a potential of the proposed technique for localization of the scaphoid bone in ultrasound images.

SPIE. MEDICAL IMAGING

9415-24, Session 5

Comparison of optimization strategy and similarity metric in atlas-to-subject registration using statistical deformation model

Yoshito Otake, Nara Institute of Science and Technology (Japan); Ryan J. Murphy, Johns Hopkins Univ. Applied Physics Lab., LLC (United States); Robert B. Grupp Jr., Johns Hopkins Univ. (United States); Yoshinobu Sato, Nara Institute of Science and Technology (Japan); Russell H. Taylor, Johns Hopkins Univ. (United States); Mehran Armand, Johns Hopkins Univ. Applied Physics Lab., LLC (United States)

A robust atlas-to-subject registration using a statistical deformation model (SDM) is presented. The SDM uses statistics of voxel-wise displacement learned from pre-computed deformation vectors of a training dataset. This allows an atlas instance to be directly translated into an intensity volume and directly compared with a patient's intensity volume for similarity optimization. Rigid and non-rigid transformation parameters were simultaneously optimized via the Covariance Matrix Adaptation – Evolutionary Strategy (CMA-ES), with image similarity used as the objective function. The algorithm was tested on CT volumes of the pelvis from 55 female subjects. A performance comparison of the CMA-ES and Nelder-Mead downhill simplex optimization algorithms with the mutual information and normalized cross correlation similarity metrics was conducted. Simulation studies using synthetic subjects were performed, as well as leave-one-out cross validation studies. Both studies suggested that mutual information and CMA-ES achieved the best performance. The leave-one-out test demonstrated 4.13 mm error with respect to the true displacement field, and 26,102 function evaluations in 180 seconds, on average. One current limitation is that the atlas creation step relies on a time-consuming and error prone non-rigid registration. This study did not investigate the atlas creation step in depth, but rather focused on the utilization of statistics of the displacement field; the predicted displacement field may be used as an initialization for a more accurate and time-consuming non-rigid registration, helping to incrementally enlarge the training dataset. We plan to extend the same framework to 2D-3D registration which will allow a 3D reconstruction from 2D projection images.

9415-25, Session 5

Incorporating target registration error into path planning

Michael Siebold, Neal Dillon, Robert J. Webster III, J. Michael Fitzpatrick, Vanderbilt Univ. (United States)

Surgery involving the drilling of bone can in some cases be accomplished robotically. Examples include joint-replacement surgery and mastoidectomy. In each case the robot is guided along a path planned on a CT image that has been registered to the physical anatomy in the operating room that is in turn registered to the robot. The registrations typically take advantage of the high accuracy of fiducial registration, but the registrations are inevitably imperfect, and as a result, the drill or mill that is guided by the robot will deviate from its planned path. The extent of the deviation can vary from point to point along the path because of the spatial variation of registration accuracy. The allowable deviation can vary spatially as well because of variation along the path in the distance of the path from nearby structures that must be avoided. Knowledge of the expected spatial pattern of registration error can be obtained from theoretical formulas or experimental measurements and can be used to modify a path to achieve desired confidence levels for sparing specified structures and has been previously presented for straight-line paths [1]. In this work, we present a general method for altering any path to achieve specified confidence levels for any spatial arrangement of structures to be avoided, and we validate the method via computer simulations for the case of mastoidectomy.

9415-26, Session 5

Adaptive deformable image registration of inhomogeneous tissues

Jing Ren, Univ. of Ontario Institute of Technology (Canada)

Physics based deformable registration can provide physically consistent image match of deformable soft tissues. In order to help radiologist/ surgeons to determine the status of malicious tumors, we often need to accurately align the regions with embedded tumors. This is a very challenging task since the tumor and the surrounding tissues have very different tissue properties such as stiffness and elasticity. In order to address this problem, based on minimum strain energy principle in elasticity theory, we propose to partition the whole region of interest into smaller sub-regions and dynamically adjust weights of vessel segments and bifurcation points in each sub-region in the registration objective function. Our previously proposed fast vessel registration is used as a component in the inner loop. We have validated the proposed method using liver MR images from human subjects. The results show that our method can detect the large registration errors and improve the registration accuracy in the neighborhood of the tumors and guarantee the registration errors to be within acceptable accuracy. The proposed technique has the potential to significantly improve the registration capability and the quality of clinical diagnosis and treatment planning.

9415-27, Session 5

Validation of model-based deformation correction in image-guided liver surgery via tracked intraoperative ultrasound: preliminary method and results

Logan W. Clements, Jarrod A. Collins, Vanderbilt Univ. (United States); Amber L. Simpson, Memorial Sloan-Kettering Cancer Ctr. (United States); Yifei Wu, Vanderbilt Univ. (United States); William R. Jarnagin, Memorial Sloan-Kettering Cancer Ctr. (United States); Michael I. Miga, Vanderbilt Univ. (United States)

Soft tissue deformation represents a significant error source in current surgical navigation systems used for open hepatic procedures. While numerous algorithms have been proposed to rectify the tissue deformation that is encountered during open liver surgery, clinical validation of the proposed methods has been limited to surface based metrics and sub-surface validation has largely been performed via phantom experiments. Tracked intraoperative ultrasound (iUS) provides a means to digitize sub-surface anatomical landmarks during clinical procedures. The proposed method involves the validation of a deformation correction algorithm for open hepatic image-guided surgery systems via sub-surface targets digitized with tracked iUS. Intraoperative surface digitizations were acquired via a laser range scanner and an optically tracked stylus for the purposes of computing the physical-to-image space registration within the guidance system and for use in retrospective deformation correction. Upon completion of surface digitization, the organ was interrogated with a tracked iUS transducer where the iUS images and corresponding tracked locations were recorded. After the procedure, the clinician reviewed the iUS images to delineate contours of anatomical target features for use in the validation procedure. Mean closest point distances between the feature contours delineated in the iUS images and corresponding 3-D anatomical model generated from the preoperative tomograms were computed to quantify the extent to which the deformation correction algorithm improved registration accuracy. The results for two patients, each using a different sub-surface anatomical feature, indicate that the deformation correction method resulted in a reduction in target error of approximately 50%.

9415-28, Session 6

Needle detection in ultrasound using the spectral properties of the displacement field: a feasibility study

Parmida Beigi, Tim E. Salcudean, Robert N. Rohling, The Univ. of British Columbia (Canada); Victoria A. Lessoway, BC Women's Hospital and Health Ctr. (Canada); Gary C. Ng, Philips Healthcare (United States)

This paper presents a new needle detection technique for ultrasound guided interventions based on the spectral properties of small displacements arising from hand tremour or intentional motion. In a block-based approach, the displacement map is computed for each block of interest versus a reference frame, using an optical flow technique. To compute the flow parameters, the Lucas-Kanade approach is used in a multiresolution and regularized form followed by a least-squares fit. Lateral and axial components of the displacement are obtained for each block of interest at consecutive frames. Magnitude-squared spectral coherency is derived between the median displacements of the reference block and each block of interest, to determine the spectral correlation. In vivo images were obtained from the tissue near the abdominal aorta to capture the extreme intrinsic body motion and insertion images were captured from a tissue-mimicking agar phantom. According to the analysis, both the involuntary and intentional movement of the needle produces coherent displacement with respect to a reference window near the insertion site. Intrinsic body motion also produces coherent displacement with respect to a reference window in the tissue; however, the coherency spectrum of intrinsic and needle motion are distinguishable spectrally. Blocks with high spectral coherency at high frequencies are selected to estimate an initial needle trajectory. The final needle trajectory is then detected from locally thresholded absolute displacement map surrounding the initial estimate. Experimental results show the localization accuracy of 1.0 mm, 0.7 mm, and 0.5 mm for hand tremour, vibrational and rotational needle motion respectively.

9415-29, Session 6

Initial assessment of a freehand 3D intra-abdominal US probe

Kevin C. Bren, Mayo Clinic (United States); Brian J. Davis, Richard A. Robb, Mayo Clinic College of Medicine (United States); David R. Holmes III, Mayo Clinic (United States)

Ultrasound has been demonstrated as a useful image guidance modality. Over the past several years, ultrasound has been used for laparoscopic procedures. Recently, we have developed a novel US probe which may be useful during laparoscopic abdominal procedures. To further enhance the utility of the probe, we proposed to use a tracked ultrasound approach to reconstruct 3D models of the anatomy.

The probe is a 14 MHz linear array mounted on a rigid shaft. An NDI Aurora sensor is attached to the probe to track the position of transducer. Calibration is based on a 4 Z-wire phantom with cross-wire verification. Once calibration has been completed, volume reconstruction is done by scanning a series of 2D images and transforming the location of the pixels of each image into its corresponding location in a 3D volume space. We applied this technique to several anthropomorphic phantoms with high-contrast and low-contrast synthetic inclusions.

Calibration accuracy was found to be within 2 mm. Volume reconstructions were measured with the elliptical method. The volume of the kidney phantom and a synthetic cyst were measured at 231.3 cm3 and 2.1 cm3, respectively. The known volume of the kidney was 243 cm3; the physical volume of the cyst was measured to be 2.6 cm3. The stone was measured to be 2.9 cm3 and reconstructed at 2.7 cm3. Future studies will include simulated resection procedures and ex-vivo demonstrations. The use of tracked ultrasound in combination with pre-acquired CT/MR datasets will allow for enhanced guidance during resection and exploratory procedures.

9415-30, Session 6

Active point out-of-plane ultrasound calibration

Alexis Cheng, Xiaoyu Guo, Johns Hopkins Univ. (United States); Haichong Zhang, Johns Hopkins Univ (United States); Hyun Jae Kang, Ralph Etienne-Cummings, Emad M. Boctor, Johns Hopkins Univ. (United States)

Image-guided surgery systems are often used to provide surgeons with informational support. Due to several unique advantages such as ease of use, real-time image acquisition, and no ionizing radiation, ultrasound is a common intraoperative medical imaging modality used in image-guided surgery systems. To perform advanced forms of guidance with ultrasound, such as virtual image overlays or automated robotic actuation, an ultrasound calibration process must be performed. This process recovers the rigid body transformation between a tracked marker attached to the transducer and the ultrasound image. Point-based phantoms are considered to be accurate, but their calibration framework assumes that the point is in the image plane. In this work, we present the use of an active point phantom and a calibration framework that accounts for the elevational uncertainty of the point. Given the lateral and axial position of the point in the ultrasound image, we approximate a circular arc in the lateral-elevational plane with a radius equal to the axial position. The standard approach transforms all of the imaged points to be a single physical point. In our approach, we minimize the distances between the arcs, with them ideally intersecting at a single point. We simulated in noiseless and noisy cases, presenting results on out-of-plane estimation errors, calibration estimation errors, and point reconstruction precision. We also performed an experiment using a robot arm as the tracker, resulting in a point reconstruction precision of 0.64mm.

9415-31, Session 7

Calibration of a needle tracking device with fiber Bragg grating sensors

Koushik Kanti Mandal, Francois Parent, Sylvain Martel, Raman Kashyap, Samuel Kadoury, Ecole Polytechnique de Montréal (Canada)

Accurate needle placement is essential in percutaneous procedures such as radiofrequency ablation (RFA) of liver tumors. Use of real-time navigation of the interventional needle can improve the targeting accuracy and obtain precise measurements of the needle tip inside the body. An emerging technology based on Fiber Bragg Grating (FBG) sensors has demonstrated the potential of estimating shapes at high speeds (up to 20 kHz), fast enough for real-time applications. In this paper, we present a calibration procedure for this novel needle tracking technology using strain measurements obtained from fiber Bragg gratings (FBGs). Three glass fibers equipped with two FBGs each were incorporated into a 19G needle. The needle shape is reconstructed based on a polynomial fitting of strain measurements obtained from the fibers. The real-time information provided by the needle tip position and shape allows tracking of the needle deflections during tissue insertion. An experimental setup was designed to yield a calibration that is insensitive to ambient temperature fluctuations and robust to slight external disturbances. We compare the shape of the 3D reconstructed needle to measurements obtained from camera images, as well as assess needle tip tracking accuracy on a ground-truth phantom. Initial results show that the tracking errors for the needle tip are under 1mm, while 3D shape deflections are minimal near the needle tip. The accuracy is appropriate for applications such as RFA of liver tumors.

9415-32, Session 7

Virtual rigid body: a new optical tracking paradigm in image guided interventions

Alexis Cheng, David S. Lee, Nishikant Deshmukh, Emad M. Boctor, Johns Hopkins Univ. (United States)

Tracking technology is often necessary for image-guided surgical interventions. Optical tracking is one option, but it suffers from line of sight and workspace limitations. Optical tracking is accomplished by attaching a rigid body onto a tool or device. This rigid body is some pattern that allows the tracker to determine its pose. A larger rigid body results in more accurate tracking, but its size is limited by the surgical workspace. This work presents a novel optical tracking method using a virtual rigid body (VRB). The VRB is a 3D rigid body generated from a light source, resulting in some pattern on a surface. Its pose can be recovered by observing the projected pattern with a stereo-camera. The rigid body's size is no longer limited. Conventional optical tracking also requires line of sight to the rigid body, whereas only the projected pattern needs to be seen with this method. Since we can project the pattern onto a region of interest, it will be in the optical tracker's view, decreasing the occurrence of occlusions. This manuscript describes the method and results compared with conventional optical tracking in an experimental setup where the tool is moved in known motions. The experiments were done using a MicronTracker and a linear stage, resulting in targeting errors of 0.38mm±0.28mm with our method compared to 0.23mm±0.22mm with conventional optical markers. Another experiment replaced the linear stage with a robot arm and resulted in rotation errors of 0.2° and 4.6° and translation errors of 0.2mm and 0.04mm respectively.

9415-33, Session 7

Integration of fiber optical shape sensing with medical visualization for minimal-invasive interventions

Torben Paetz, Fraunhofer MEVIS (Germany); Christian Waltermann, Martin Angelmahr, Fraunhofer-Institut für Nachrichtentechnik Heinrich-Hertz-Institut (Germany); Darko Ojdanic, Fraunhofer MEVIS (Germany); Wolfgang Schade, Michael Witte, Fraunhofer-Institut für Nachrichtentechnik Heinrich-Hertz-Institut (Germany); Horst K. Hahn, Fraunhofer MEVIS (Germany)

We present a fiber optical shape sensing system to track the shape of a standard telecom fiber with fiber Bragg grating (FBG). FBG is using the effect that a temperature difference, a strain, an acceleration or a tilt changes the diffraction index, which is caused by concave gratings inside the fiber. Recording of these diffractions by a special interrogator allows the measurement of differing environmental influences

FBGs combine the advantages of existing tracking solutions: they can track instruments inside the body (no line of sight restriction), can be used inside the MR (no interference with electro-magnetic devices), and can be integrated in needles and catheters (small size of the fiber). In contrast to other tracking devices it is possible to track several points along the fiber, allowing to reconstruct the shape of fiber. The shape sensing information is combined with a medical visualization platform to visualize the shape sensing information together with medical images and post-processing results like 3D models, vessel graphs, or segmentation results. We pass the data from the shape sensing application to the visualization application via a lightweight UDP protocol, calibrate the shape sensing data with the image/model data using a robust calibration approach that needs three or more points correspondences in the shape and image coordinate system, and have a real-time visualization of the transformed fiber for tracking and navigation in the medical data. The framework has a modular nature to use it for medical applications like catheter or needle based interventions.

9415-34, Session 7

4DCBCT-based motion modeling and 3D fluoroscopic image generation for lung cancer radiotherapy

Salam Dhou, Martina Hurwitz, Brigham and Women's Hospital (United States) and Dana-Farber Cancer Institute (United States) and Harvard Medical School (United States); Pankaj Mishra, Varian Medical Systems, Inc. (United States); Ross Berbeco, Brigham and Women's Hospital, Dana-Farber Cancer Institute, and Harvard Medical School (United States); John Lewis, Brigham and Women's Hospital (United States) and Dana-Farber Cancer Institute (United States) and Harvard Medical School (United States)

A method is developed to build patient-specific motion models based on 4DCBCT images taken at treatment time and use them to generate 3D time-varying images (referred to as 3D fluoroscopic images). Motion models are built by applying Principal Component Analysis (PCA) on the displacement vector fields (DVFs) estimated by performing deformable image registration on each phase of 4DCBCT relative to a reference phase. The resulting PCA coefficients are optimized iteratively by comparing 2D projections captured at treatment time with projections estimated using the motion model. The optimized coefficients are used to generate 3D fluoroscopic images. The method is evaluated using anthropomorphic physical and digital phantoms reproducing real patient trajectories. For physical phantom datasets, the average tumor localization error (TLE) and (95th percentile) in two datasets were 0.95 (2.2) mm. For digital phantoms assuming superior image quality of 4DCT and no anatomic or positioning disparities between 4DCT and treatment time, the average TLE and the image intensity error (IIE) in six datasets were smaller using 4DCT-based motion models. When simulating positioning disparities and tumor baseline shifts at treatment time compared to planning 4DCT, the average TLE (95th percentile) and IIE were 4.2 (5.4) mm and 0.15 using 4DCT-based models, while they were 1.2 (2.2) mm and 0.10 using 4DCBCT-based ones, respectively. 4DCBCT-based models were shown to perform better when there are positioning and tumor baseline shift uncertainties at treatment time. Thus, generating 3D fluoroscopic images based on 4DCBCT-based motion models can capture both inter- and intra- fraction anatomical changes during treatment.

9415-35, Session 7

Surgical tool detection and tracking in retinal microsurgery

Mohamed S. Alsheakhali, Mehmet Yigitsoy, Abouzar Eslami, Nassir Navab, Technische Univ. München (Germany)

Visual tracking of surgical instruments is an essential part of eye surgery, and plays an important rule for the surgeons as well as it is a key component of robotics assistance during the operation time. The difficulty of detecting and tracking medical instruments in-vivo images comes from its deformable shape, changes in brightness, and the presence of the instrument shadow. This paper introduces a new approach to detect the tip of surgical tool and its width regardless of its head shape and the presence of the shadows or vessels. The approach relies on integrating structural information about the strong edges from the RGB color model, and the tool location-based information from L*a*b color model. The probabilistic Hough transform has been applied to get the strongest straight lines in the RGB-images, and based on information from the L* and a*, one of these candidates lines is selected as the edge of the tool shaft. Based on that line, the tool slope, the tool centerline and the tool tip could be detected. The tracking takes place by keeping track of the last detected tool tip and the tool slope, and filtering the Hough lines within a box around the last detected tool tip based on the slope differences. Experimental results demonstrate the high accuracy

achieved in term of detecting the tool tip position, the tool joint point position, and the tool centerline. The approach also meets the real time requirements.

9415-36, Session 7

A biomechanical approach for in vivo lung tumor motion prediction during external beam radiation therapy

Elham Karami, Western Univ. (Canada) and Imaging Research Labs., Robarts Research Institute (Canada); Stewart Gaede, Western Univ. (Canada); Ting-Yim Lee, Lawson Health Research Institute (Canada) and Imaging Research Labs., Robarts Research Institute (Canada) and Western Univ. (Canada); Abbas Samani, The Univ. of Western Ontario (Canada) and Imaging Research Laboratories, Robarts Research Institute (Canada) and Western Univ. (Canada)

Lung Cancer is the leading cause of cancer death in both men and women. Among various treatment methods currently being used in the clinic, External Beam Radiation Therapy (EBRT) is used widely not only as the primary treatment method, but also in combination with chemotherapy and surgery. However, this method may lack desirable dosimetric accuracy because of respiration induced tumor motion. Recently, biomechanical modeling of the respiratory system has become a popular approach for tumor motion prediction and compensation. This approach requires reasonably accurate data pertaining to thoracic pressure variation, diaphragm position and biomechanical properties of the lung tissue in order to predict the lung tissue deformation and tumor motion. In this paper, we present preliminary results of an in vivo study obtained from a Finite Element Model (FEM) of the lung developed to predict tumor motion during respiration. An important novel aspect of the proposed method is that the lung's tissue incompressibility parameter was considered to be variable during respiration. In addition, an optimization framework was used to obtain patients specific thoracic pressure values and incompressibility parameter versus time to be used in the FE model. In order to assess the FE model, the predicted tumor volume at each phase of respiration was compared with the corresponding actual one .The results indicate that there is a minimum tumor volume overlap of 72% between the actual tumor and its predicted model.

9415-37, Session 7

Can coffee improve image guidance?

Raul Wirz, Ray A. Lathrop, Vanderbilt Univ. (United States); Jessica Burgner-Kahrs, Leibniz Univ. Hannover (Germany); Paul T. Russell III, Robert J. Webster III, Isuru Godage, Vanderbilt Univ. (United States)

Based on fiducial configurations and the registration methods used, one would expect excellent accuracy at the skull base when commercial image guidance systems are used. Yet anecdotally surgeons observe large errors in some cases, and excellent accuracy in others. We hypothesize that this is due to operating room personnel accidentally bumping the reference rigid body during patient preparation or the surgery itself. In this paper we explore the registration error at the skull base that is induced by simulated bumping of the rigid body (application/removal of 9.81 N in various directions), and find that large errors can occur. To address this, we propose a new fixation method for the rigid body based on granular jamming using coffee granules. Our results show that use of our granular jamming fixation device prototype reduces registration error by 28%-68% (depending on bump direction) in comparison to the standard Brainlab reference headband.

9415-38, Session 8

Deep learning for automatic localization, identification, and segmentation of vertebral bodies in volumetric MR images

Amin Mahdi Suzani, Abtin Rasoulian, Alexander Seitel, Sidney Fels, Robert N. Rohling, Purang Abolmaesumi, The Univ. of British Columbia (Canada)

This paper proposes an automatic method for vertebra localization, labeling, and segmentation in multi-slice Magnetic Resonance (MR) images. Prior works in this area on MR images mostly require user interactions while our method is fully automatic. Cubic intensity-based features are extracted from image voxels. A deep learning approach is used for simultaneous localization and identification of vertebrae. The localized points are refined by local thresholding in the region of the detected vertebral column. Thereafter, a statistical multi-vertebrae model is initialized by the localized vertebrae. An iterative Expectation Maximization technique is used to register the vertebral body of the model to the image edges and obtain a segmentation of lumbar vertebral bodies. The method is evaluated by applying to nine volumetric MR images of the spine. The results demonstrate 100% vertebra identification and mean error of below 2.8 mm for 3D segmentation. Computation time is less than three minutes per high-resolution volumetric image.

9415-39, Session 8

Grading remodeling severity in asthma based on airway wall thickening index and bronchoarterial ratio measured with MSCT

Catalin Fetita, Télécom SudParis (France); Pierre-Yves Brillet, Univ. Paris 13 (France) and Assistance Publique Hopitaux de Paris (France); Christopher Brightling, Univ. of Leicester (United Kingdom) and Glenfield Hospital (United Kingdom); Philippe A. Grenier, Univ. Paris 6 (France) and Assistance Publique Hopitaux de Paris (France)

Defining therapeutic protocols in asthma and monitoring patient response require a more in-depth knowledge on the disease severity and treatment outcome based on quantitative indicators.

This paper aims at grading severity in asthma based on objective morphological measurements obtained in automated fashion from 3-D multi-slice computed tomography (MSCT) image datasets. These measures attempt to capture and quantify the airway remodeling process involved in asthma, both at the level of the airway wall thickness and airway lumen. Two morphological changes are thus targeted here, (1) the airway wall thickening measured as a global index characterizing the increase of wall thickness above a normal value of wall-to-lumen-radius ratio, and (2) the bronchoarterial ratio index assessed globally from numerous locations in the lungs.

The combination of these indices provides a grading of the severity of the remodeling process in asthma which correlates with the known phenotype of the patients investigated.

9415-40, Session 8

Evaluation metrics for bone segmentation in ultrasound

Matthew Lougheed, Gabor Fichtinger, Tamas Ungi, Queen's Univ. (Canada)

PURPOSE: Tracked ultrasound is a safe alternative to X-ray for imaging bones. The interpretation of bony structures is challenging as ultrasound has

no specific intensity characteristic of bones. Several image segmentation algorithms have been devised to identify bony structures. We propose an open-source framework that would aid in the development and comparison of such algorithms by quantitatively measuring segmentation performance in the ultrasound images. METHODS: True-positive and false-negative metrics used in the framework quantify algorithm performance in special ground-truth areas. Different ground-truth for these metrics are defined manually for both metrics. Tests on a commonly used bone segmentation algorithm verified the accuracy of the analysis. RESULTS: The framework was implemented as an open-source module of the 3D Slicer platform. The ground truth tests verified that the framework correctly calculates the implemented metrics. CONCLUSION: The developed framework provides a convenient way to evaluate bone segmentation algorithms. The implementation fits in a widely used application for segmentation algorithm prototyping. Future algorithm development will benefit by monitoring the effects of adjustments to an algorithm in a standard evaluation framework.

9415-41, Session 8

Fast and intuitive segmentation of gyri of the human brain

Florian Weiler, Horst K. Hahn, Fraunhofer MEVIS (Germany)

The cortical surface of the human brain consists of a large number of folds forming valleys and ridges, the gyri and sulci. Often, it is desirable to perform a segmentation of a brain image into these underlying structures in order to assess parameters relative to these smaller, functional components. Typical examples for this include measurement of cortical thickness for individual functional areas, or the corellation of functional areas derived from fMRI data to corresponding anatomical areas seen in structural imaging. In this paper, we present a novel interactive technique, which allows for fast and intuitive segmentation of these functional areas from T1-weighted MR images of the brain. It works purely on the input voxel data, eliminating the requirement to explicitly reconstruct the brains surface.

Our method is based on the observation, that every gray-matter voxel of the brain is somewhere connected to a white matter voxel. In consequence, every WM voxel on the interface between WM and GM clusters a certain number of GM voxels. This fact can be exploited for gyral segmentation by first selecting a small sample of voxels from a gyrus in question, e.g. by means of a contour drawn on the brains surface, afterwards identifying the WM voxels connected to this sample, and finally clustering all GM voxels connected to this WM structure. This method essentially allows segmentation of gyri by simply drawing on the brains surface, allowing an expert user to easily segment structures of interest based on his expectation.

9415-42, Session 8

Automatic anatomy recognition in PET/CT Images

Huiqian Wang, Univ. of Pennsylvania (United States) and Chongqing Univ. (China); Jayaram K. Udupa, Univ. of Pennsylvania (United States); Dewey Odhner, Yubing Tong, The Univ. of Pennsylvania Health System (United States); Liming Zhao, Univ. of Pennsylvania (United States) and Chongqing Univ. (China); Drew A. Torigian, Hospital of the Univ. of Pennsylvania (United States)

With the rapid growth of PET-CT-based medical applications, body-wide anatomy recognition in whole-body PET/CT images becomes crucial for quantifying body-wide disease burden. This, however, is a challenging problem and seldom studied due to unclear anatomy reference frame and low spatial resolution of PET images and low contrast and spatial resolution of the associated low-dose CT images. We previously developed an automatic anatomy recognition (AAR) system [1] whose applicability was demonstrated on diagnostic CT and MR images in different body regions on 35 organs. The aim of the present work is to investigate strategies for adapting the previous AAR system to low-dose CT and PET images toward automated body-wide disease quantification. Our adaptation of the previous AAR methodology to PET-CT images in this paper focuses on 10 organs in two body regions – thorax and abdomen – and consists of the following steps: collecting whole body PET-CT images from existing patient image databases, delineating all organs in these images, modifying the previous hierarchical models built from diagnostic CT images to account for differences in appearance in low-dose CT and PET images, automatically locating objects in these images following object hierarchy, and evaluating performance. Our preliminary evaluations indicate that the performance of the AAR approach on low-dose CT images achieves object localization accuracy within 2 voxels and within 3 voxels on just the PET images, which are comparable to the accuracies achieved on diagnostic CT images. Object recognition on low-dose CT/PET images without requiring diagnostic CT seems feasible.

9415-43, Session 9

Atlas and feature based 3D pathway visualization enhancement for skull base pre-operative fast planning from head CT

Nava Aghdasi, Yangming Li, Angelique Berens, Kris S Moe, Randall A Bly, Blake Hannarord, Univ. of Washington (United States)

Minimally invasive neuroendoscopic surgery continues into increase in popularity as a substitute for open craniotomy, because of less postoperative pain, faster recovery and less retraction on the frontal lobe. For skull base surgery, surgeons manually and iteratively change both window and level of CT slices for each possible entry point, in order to achieve the optimal surgical plan. This process is slow and error-prone, because entry points are continuously located on the whole surface. In this paper, we describe a rapid pre-operative planning system for skull base surgery planning. The software rebuilds a 3D model from CT slices and allows surgeons to select the target point. Surgeons then set an entry portal and drag it to search for the best entry point. In order to solve the key problem in the project, which is poor visualization effect for CT scans, we proposed an atlas and feature based regional transfer functions search method. The method first extracts bones and features, such as carotid canal and pars nervosa jugular foramen, from CT scans. Then it registers the model with the atlas to refine contours. Lastly, different transfer functions are then applied to contours in the 3D model for better volume rendering results. The experimental results show: 1, the proposed method improves the visualization effect without explicit segmentation of CT scans, which is both difficult and error-prone; 2, surgeons can easily plan with the software with minimal manual adjustment of visualization effect; 3, the software improves speed and efficacy of planning skull base surgery.

9415-44, Session 9

Design and first implementation of business process visualization for a task manager supporting the workflow in an operating room

Elena Fink, Markus Wiemuth, Oliver Burgert, Reutlingen Univ. (Germany)

An operating room is a stressful work environment. Nevertheless, all involved persons have to work safely as there is no space for making mistakes. To ensure a high level of concentration and seamless interaction, all involved persons have to know their own tasks and the tasks of their colleagues. The entire team must work synchronously at all times. To optimize the overall workflow, a task manager supporting the team was developed.

In parallel, a common conceptual design of a business process visualization was developed, which makes all the relevant information accessible in real-time during a surgery. In this context an overview of all processes in the operating room was created and different concepts for the graphical representation of these user-dependent processes were developed.

9415-45, Session 9

Quantitative wavelength analysis and image classification for intraoperative cancer diagnosis with hyperspectral imaging

Guolan Lu, Xulei Qin, Dongsheng Wang, Georgia Z. Chen, Baowei Fei, Emory Univ. (United States)

Complete surgical removal of tumor tissue is essential for the postoperative prognosis of patients. Intraoperative tumor imaging and visualization are an important step in aiding surgeons to evaluate and resect tumor tissues in real time, thus enabling more complete resection of diseased tissue and better conservation of healthy tissue. As an emerging modality, hyperspectral imaging (HSI) holds great potential for comprehensive and objective intraoperative cancer assessment. In this paper, we explored the possibility of intraoperative tumor detection and visualization during surgery using hyperspectral imaging in the wavelength range of 450 nm - 900 nm in an animal experiment. We proposed a novel classification algorithm for glare removal and cancer detection from surgical hyperspectral images, and detected the tumor margins with an average sensitivity and specificity of 94.4%, and 98.3%, respectively.

9415-46, Session 9

Methods for a fusion of optical coherence tomography and stereo camera image data

Jan N. Bergmeier, Dennis Kundrat, Andreas Schoob, Lüder A. Kahrs, Tobias Ortmaier, Leibniz Univ. Hannover (Germany)

This work investigates combination of Optical Coherence Tomography and two cameras, observing a microscopic scene. Stereo vision provides realistic images, but is limited in terms of penetration depth. Optical Coherence Tomography (OCT) enables access to subcutaneous structures, but 3D-OCT volume data do not give the surgeon a familiar view. The extension of the stereo camera setup with OCT imaging combines the benefits of both modalities. In order to provide the surgeon with a convenient integration of the OCT into the vision interface, we present an automated image processing analysis of OCT and stereo camera data as well as combined imaging as augmented reality visualization. Therefore, we care about image noise, perform segmentation as well as develop proper registration objects and registration methods. The registration between stereo camera and OCT results in a Root Mean Square error of 284 μm as average of five measures. The presented methods are fundamental for fusion of both imaging modalities. Augmented reality is shown as application of the results. Further developments lead to fused visualization of subcutaneous structures, as information of the OCT images, into stereo vision.

9415-47, Session 9

Self-calibration of cone-beam CT geometry using 3D-2D image registration: development and application to tasked-based imaging with a robotic C-arm

Sarah Ouadah, Joseph W. Stayman, Grace J. Gang, Ali Uneri, Johns Hopkins Univ. (United States); Tina Ehtiati, Siemens Healthcare (United States); Jeffrey H. Siewerdsen, Johns Hopkins Univ. (United States)

Robotic C-arm systems are capable of general noncircular orbits whose trajectories can be driven by the particular imaging task. However obtaining accurate calibrations for reconstruction in such geometries can be a challenging problem. This work proposes a method to perform a unique geometric calibration of an arbitrary C-arm orbit by registering 2D projections to a previously acquired 3D image to determine the transformation parameters representing the system geometry. Experiments involved a cone-beam CT (CBCT) bench system, a robotic C-arm, and three phantoms. A robust 3D-2D registration process was used to compute the 9 DOF transformation between each projection and an existing 3D image by maximizing normalized gradient information with a digitally reconstructed radiograph (DRR) of the 3D volume. The quality of the resulting "self calibration" was evaluated in terms of the agreement with an established calibration method using a BB phantom as well as image quality in the resulting CBCT reconstruction. The self-calibration yielded CBCT images without significant difference in spatial resolution from the standard ("true") calibration methods (p-value >0.05 for all three phantoms), and the differences between CBCT images reconstructed using the "self" and "true" calibration methods were on the order of 10-3 mm-1. Maximum error in magnification was 3.2%, and ray placement was within 0.5 mm. The proposed geometric "self" calibration provides a means for 3D imaging on general non-circular orbits in CBCT systems for which a geometric calibration is either not available or not reproducible. The method forms the basis of advanced "task-based" 3D imaging methods now in development for robotic C-arms.

9415-48, Session 9

A multimodal imaging framework for enhanced robot-assisted partial nephrectomy guidance

Ryan J. Halter, Xiaotian Wu, Dartmouth College (United States); Alex Hartov, Thayer School of Engineering at Dartmouth (United States); John Seigne, Dartmouth College (United States); Shadab Khan, Thayer School of Engineering at Dartmouth (United States)

Background: Robot-assisted laparoscopic partial nephrectomies (RALPN) are performed to treat patients with locally confined renal carcinoma. There are well-documented benefits to performing partial (opposed to radical) kidney resections and to using robot-assisted laparoscopic (opposed to open) approaches. However, there are challenges in identifying tumor margins and critical benign structures including blood vessels and collecting systems during current RALPN procedures.

Purpose: The primary objective of this effort is to couple multiple image and data streams together to augment visual information currently provided to surgeons performing RALPN and ultimately ensure complete tumor resection and minimal damage to functional structures (i.e. renal vasculature and collecting systems).

Methods: To meet this challenge we have developed a framework and performed initial feasibility experiments to couple pre-operative high-resolution anatomic images with intraoperative MRI, ultrasound (US) and optical-based surface mapping and kidney tracking. With these registered images and data streams, we aim to overlay the high-resolution contrast-enhanced anatomic (CT or MR) images onto the surgeon's view screen for enhanced guidance.

Results: To date we have integrated the following components of our framework: 1) a method for tracking an intraoperative US probe to extract the kidney surface and a set of embedded kidney markers, 2) a method for co-registering intraoperative US scans with pre-operative MR scans, and 3) a method for deforming pre-op scans to match intraoperative scans. These components have been evaluated through phantom studies to demonstrate protocol feasibility.

9415-49, Session 10

Twenty-five years of error *(Keynote Presentation)*

J. Michael Fitzpatrick, Vanderbilt Univ. (United States)

Today, the phrase, "Target Registration Error", typically shortened to TRE, is an integral part of the vernacular of both surgical guidance and image registration, but it was not always so. This terminology, along with "Fiducial Registration Error" and "Fiducial Localization Error" was developed circa 1990 to facilitate the communication of information among researchers who were contending with the errors that arise when one view of a patient is aligned with another, particularly when that alignment is based on fiducial markers. The work required to develop a theoretical understanding of these errors and to develop algorithms and experimental methods to probe them has involved many people and many institutions, and it continues today. This twenty-five year effort is the subject of this address, but we will not dwell on the details, almost all of which have been presented first at this very same symposium. Instead we will focus on the backstory. It is a story of people and events, of lab rivalry and cooperation, of heroes and villains, of sour reviews and sweet vindication, of disappointment when things keep going wrong, and gratification when they finally go right. And it even includes a murder mystery. This address is meant to be entertaining, but it is hoped that it might also send an encouraging message to those researchers, particularly students, who are having troubles of their own. And that message is that setbacks and criticism today do not mean that success won't come tomorrow.

9415-50, Session 10

Known-component 3D-2D registration for image guidance and quality assurance in spine surgery pedicle screw placement

Ali Uneri, Joseph W. Stayman, Tharindu D. Silva, Adam S. Wang, Johns Hopkins Univ. (United States); Gerhard Kleinszig, Sebastian Vogt, Siemens AG (Germany); Jean-Paul Wolinsky, Ziya L. Gokaslan, Jeffrey H. Siewerdsen, Johns Hopkins Univ. (United States)

Purpose: To extend the functionality of radiographic / fluoroscopic imaging systems already within standard spine surgery workflow to: (1) provide guidance of surgical device analogous to an external tracking system; and (2) provide intraoperative quality assurance (QA) of the surgical product.

Methods: Using fast, robust 3D-2D registration in combination with 3D models of known components (surgical devices), the 6 DOF pose determination was solved to relate tool positions relative to 2D projection images and 3D preoperative CT in near-real-time. The algorithm employs the covariance matrix adaptation evolution strategy (CMA-ES) to maximize gradient similarity (normalized gradient information) between measured projections and forward projections of the known tools. Guidance accuracy was evaluated in a spine phantom in terms of target registration error (TRE) and geodesic difference of quaternions. QA of the surgical product was evaluated in a cadaver study in terms of screw placement relative to the surgical plan.

Results: Transpedicle tools (needles and spine screws) were successfully tracked with TRE <2 mm TRE and angular error <0.5° given projection views separated by at least >30° (easily accommodated on a mobile C-arm). QA of the surgical product based on 3D2D registration demonstrated the detection of pedicle screw breach with TRE <1.5 mm and could be intuitively displayed to the surgeon for evaluation relative to surgical planning and a clinical acceptance win-dow.

Conclusions: 3D2D registration combined with 3D models of known surgical components provides a novel method for near-real-time navigation and QA using a mobile C-arm without external trackers or fiducial markers. Ongoing work includes determination of optimal views based on component shape and trajectory, improved robustness to anatomical deformation, and expanded preclinical testing in spine and intracranial surgeries.

9415-51, Session 10

Device and methods for "gold standard" registration of clinical 3D and 2D cerebral angiograms

Hennadii Madan, Bo?tjan Likar, Franjo Pernu?, Ziga Spiclin, Univ. of Ljubljana (Slovenia)

Image-guided surgical procedures currently rely mostly on the analysis and visualization of live 2D X-ray images. By spatial co-registration and fusion of the live 2D images with the information-rich 3D pre-operative images and treatment plans, the intra-operative guidance and treatment delivery can be substantially improved. Although for this purpose several 3D-2D image registration methods were developed, their translation into clinical image-guidance systems is limited because these methods generally lack an extensive and objective validation. Such validation should be performed on a large number of clinical image datasets with known accurate and reliable reference 3D-2D registration or "gold standard", which, unfortunately, received little attention in the literature, because the "gold standard" is very difficult to obtain on clinical data. Here we present a device and methods for the creation of "gold standard" for, but not limited to, datasets of 3D and 2D cerebral angiograms. As fiducial markers we used steel balls firmly sewed in an elastic headband, which can be tightly attached to the patient's head. The creation of "gold standard" creation involved marker detection and identification in 3D and 2D images, their reconstruction from 2D to 3D and co-registration in 3D to obtain optimal pose of the C-arm in each view and optimal rigid-body pose of the 3D image. The automation eliminated all manual input and reduced the time to obtain the "gold standard" to less than one minute, while the "gold standard" creation method provided 3D-2D registrations of 15 datasets of clinical cerebral angiograms with a sub-0.1 mm precision.

9415-52, Session 11

Data fusion for planning target volume and isodose prediction in prostate brachytherapy

Saman Nouranian, Mahdi Ramezani, The Univ. of British Columbia (Canada); S. Sara Mahdavi, The Univ. of British Columbia (Canada) and British Columbia Cancer Agency (Canada); Ingrid Spadinger, William J. Morris, British Columbia Cancer Agency (Canada); Tim E. Salcudean, The Univ. of British Columbia (Canada); Purang Abolmaesumi, British Columbia Cancer Agency (Canada)

In low-dose prostate brachytherapy treatment, a large number of radioactive seeds is implanted in and adjacent to the prostate gland. Planning of this treatment involves the determination of a Planning Target Volume (PTV), followed by defining the optimal number of seeds, needles and their coordinates for implantation. The two major planning tasks, i.e. PTV determination and seed definition, are associated with inter- and intra-expert variability. Moreover, since these two steps are performed in sequence, the variability is accumulated in the overall treatment plan. In this paper, we introduce a model based on a data fusion technique that enables joint determination of PTV and the minimum Prescribed Isodose (mPD) map. The model captures the correlation between different information modalities consisting of transrectal ultrasound (TRUS) volumes, PTV and isodose contours. We take advantage of joint Independent Component Analysis (jICA) as a linear decomposition technique to obtain a set of joint components that optimally describe such correlation. We perform a component stability analysis to generate a model with stable parameters that predicts the PTV and isodose contours solely based on a new patient TRUS volume. We propose a framework for both modeling and prediction processes and evaluate it on a dataset of 60 brachytherapy treatment records. We show PTV prediction error of 10.02±4.5% and the V100 isodose overlap of 97±3.55% with respect to the clinical gold standard.

9415-53, Session 11

Optimizing MRI-targeted fusion prostate biopsy: the effect of systematic error and anisotropy on tumor sampling

Peter R. Martin, Derek W. Cool, Cesare Romagnoli, Aaron Fenster, Aaron D. Ward, Western Univ. (Canada)

Magnetic resonance imaging (MRI)-targeted, 3D transrectal ultrasound (TRUS)-guided "fusion" prostate biopsy aims to reduce the 21–47% false negative rate of clinical 2D TRUS-guided sextant biopsy. Although it has been reported to double the positive yield, MRI-targeted biopsy still has a substantial false negative rate. Therefore, we propose optimization of biopsy targeting to meet the clinician's desired tumor sampling probability, optimizing needle targets within each tumor and accounting for uncertainties due to guidance system errors, image registration errors, and irregular tumor shapes. As a step toward this optimization, we obtained multiparametric MRI (mpMRI) and 3D TRUS images from 49 patients. A radiologist and radiology resident contoured 81 suspicious regions, yielding 3D surfaces that were registered to 3D TRUS. We estimated the probability, P, of obtaining a tumor sample with a single biopsy, and investigated the effects of systematic errors and anisotropy on P. Our experiments indicated that a biopsy system's lateral and elevational errors have a much greater effect on sampling probabilities, relative to its axial error. We have also determined that for a system with RMS error of 3.5 mm, tumors of volume 1.9 cm^3 and smaller may require more than one biopsy core to ensure 95% probability of a sample with 50% core involvement, and tumors 1.0 cm^3 and smaller may require more than two cores.

9415-54, Session 11

Navigated placement of markers for motion compensation in radiotherapy

Adrian Winterstein, Keno März, Alfred M. Franz, Deutsches Krebsforschungszentrum (Germany); Mohammadreza Hafezi, Nassim Fard, Ruprecht-Karls-Univ. Heidelberg (Germany); Florian Sterzing, Deutsches Krebsforschungszentrum (Germany); Arianeb Mehrabi, Ruprecht-Karls-Univ. Heidelberg (Germany); Lena Maier-Hein, Deutsches Krebsforschungszentrum (Germany)

One of the main challenges in radiotherapy is the movement of the tumor caused by respiration. Markers can be implanted around the tumor prior to radiation for precise treatment and tracking of tumor movement. Accurate placement of these markers while taking into account the target and critical structures, however, represents a major challenge for physicians. In particular, because the spatial configuration of the markers effects the accuracy of motion compensation. While computer-assisted needle insertion has been an active field of research in the past decades, the challenge of navigated marker placement has not been addressed. This work presents a system to support marker implantation in radiotherapy, allowing for placing the markers already during an open liver surgery. In the case of radiotherapy following surgery the patient can be spared the trauma of an additional intervention for the marker insertion. A combination of a mobile electromagnetic field generator and an ultrasonic probe forms a combined modality for simultaneous localization of the applicator and imaging of the tumor. A phantom study showed that the developed assistance system allows for an accurate and fast marker placement. The mean divergence of the markers from the planned security distance to the tumor was 2.1 mm +/- 1.5 mm. The distance of the centers of mass of target structures and markers was 4.4 mm on average. An intervention took under 10 minutes on average. We conclude that our system facilitates the placement of markers in suitable configurations even for surgeons without extensive experience in needle insertions.

9415-55, Session 11

Image guidance improves localization of sonographically occult colorectal liver metastases

Universe Leung, Memorial Sloan-Kettering Cancer Ctr. (United States); Amber L. Simpson, Vanderbilt Univ. (United States); Lauryn B. Adams, William R. Jarnagin, Memorial Sloan-Kettering Cancer Ctr. (United States); Michael I. Miga, Vanderbilt Univ. (United States); T. Peter Kingham, Memorial Sloan-Kettering Cancer Ctr. (United States)

Assessing the therapeutic benefit of surgical navigation systems is a challenging problem in image-guided surgery. The exact clinical indications for patients that may benefit from these systems is not always clear, particularly for abdominal surgery where image-guidance systems have failed to take hold in the same way as orthopedic and neurosurgical applications. We report interim analysis of a prospective clinical trial for localizing small colorectal liver metastases using the Explorer system (Pathfinder Technologies, Nashville, TN). Colorectal liver metastases are small lesions that can be difficult to identify with conventional intraoperative ultrasound due to echogeneity changes in the liver as a result of chemotherapy and other preoperative treatments. Interim analysis with eighteen patients shows that 9 of 15 (60%) of these occult lesions could be detected with image guidance. Image guidance changed intraoperative management in 3 (17%) cases. These results suggest that image guidance is a promising tool for localization of small occult liver metastases.

9415-56, Session PSMon

Medical image segmentation using object atlas versus object cloud models

Renzo Phellan, Alexandre X. Falcão, Univ. Estadual de Campinas (Brazil); Jayaram K. Udupa, Univ. of Pennsylvania (United States)

Medical image segmentation is crucial for quantitative organ analysis and surgical planning. Since interactive segmentation is not practical in a production-mode clinical setting, automatic methods based on 3D object appearance models have been proposed. Among them, approaches based on object atlas are the most actively investigated. A key drawback of these approaches is that they require a time-costly image registration process to build and deploy the atlas. Object cloud models (OCM) have been introduced to avoid registration, considerably speeding up the whole process, but they have not been compared to object atlas models (OAM). The present paper fills this gap by presenting a comparative analysis of the two approaches in the task of individually segmenting nine anatomical structures of the human body. Our results indicate that OCM achieve a statistically significant better accuracy for seven anatomical structures, in terms of Dice Similarity Coefficient and Average Symmetric Surface Distance.

9415-57, Session PSMon

Interactive non-uniformity correction and intensity standardization of MR images

Yubing Tong, Jayaram K. Udupa, Dewey Odhner, Shobhit Sharma, Drew A. Torigian, Univ. of Pennsylvania (United States)

Image non-uniformity and intensity non-standardness are two major hurdles encountered in human and computer interpretation and analysis of magnetic resonance (MR) images. Automated methods for image

non-uniformity correction (NC) and intensity standardization (IS) may fail because solutions for them require identifying regions representing the same tissue type for a couple of different tissues, and the automatic strategies, irrespective of the approach, may fail in this task. This paper presents interactive strategies to overcome this problem: interactive NC and interactive IS. The methods require sample tissue regions to be specified for several different types of tissues. Interactive NC precisely estimates the degree of non-uniformity at each voxel in a given image, builds a global function for non-uniformity correction, and then corrects image to improve quality. Interactive IS includes two steps: a calibration step and a transformation step. In the first step, tissue intensity signatures of each tissue from a few subjects are utilized to set up key landmarks in a standardized intensity space. In the second step, a piecewise linear intensity mapping function is built between the same tissue signatures derived from the given image and those in the standardized intensity space to transform the intensity of the given image into standardized intensity. Preliminary results on abdominal T1-weighted MR images of 20 subjects show that interactive NC and IS are feasible and can significantly improve image quality when automatic methods fail. Interactive IS for MR images combined with interactive NC can substantially improve numeric characterization of tissues especially when automated methods fail.

9415-58, Session PSMon

Evaluation of input devices for teleoperation of concentric tube continuum robots for surgical tasks

Carolin Fellmann, Daryoush Kashi, Jessica Burgner-Kahrs, Leibniz Univ. Hannover (Germany)

For those minimally invasive surgery where conventional surgical instruments cannot reach the surgical site due to their straight structure and rigidity, concentric tube continuum robots are a promising technology because of their small size (comparable to a needle) and maneuverability. These flexible, compliant manipulators can easily access hard to reach anatomical structures, e.g. by turning around corners. By teleoperating the robot the surgeon stays in direct control at any time.

In this paper, three off-the-shelf input devices are considered for teleoperation of a concentric tube continuum robot: a 3D mouse, a gamepad, and a 3 degrees of freedom haptic input device. Three tasks which mimic relevant surgical maneuvers are performed by 12 subjects using each input device: reaching specific locations, picking and placing objects from one location to another, and approaching the surgical site through a restricted pathway. We present quantitative results (task completion time, accuracy, etc.), a statistical analysis, and empirical results (questionnaires). Overall, the performance of subjects using the 3D mouse was superior to the performance using the other input devices. The subjective ranking of the 3D mouse by the subjects confirms this result.

9415-59, Session PSMon

Additive manufacturing of patient-specific tubular continuum manipulators

Ernar Amanov, Thien-Dang Nguyen, Jessica Burgner-Kahrs, Leibniz Univ. Hannover (Germany)

Continuum robots, which are composed of multiple concentric precurved elastic tubes, provide more dexterity than traditional surgical instruments at the same diameter. The tubes can be precurved such that the resulting manipulator fulfills surgical task requirements. Up to now the only material used for the component tubes of those manipulators is NiTi, a superelastic shape-memory alloy of nickel and titan. NiTi is a cost-intensive material and fabrication processes are complex, requiring (proprietary) technology, e.g. for shape setting. In this paper, we evaluate component tubes made of 2 thermoplastic materials (PLA and nylon) using fused filament fabrication technology (3D printing). This enables quick and cost-effective production of custom, patient-specific continuum manipulators, produced on demand.

Thermoplastic tube elasticity is evaluated experimentally for 7 fabricated tubes with diameters and shapes equivalent to those of NiTi tubes. Tubes made of nylon exhibit comparable properties to those made of NiTi. We further demonstrate a concentric tube continuum manipulator composed of 3 nylon tubes in a transnasal, transsphenoidal skull base surgery scenario in vitro.

9415-60, Session PSMon

Towards the development of a spring-based continuum robot for neurosurgery

Yeongjin Kim, Shing Shin Cheng, Jaydev P. Desai, Univ. of Maryland, College Park (United States)

Brain tumor, be it primary or metastatic, is usually life threatening due to the uncontrolled growth of abnormal cells. The risks involved in carrying out surgery within such a vital organ can cause severe anxiety in cancer patients. However, neurosurgery, which remains one of the more effective ways of treating brain tumors, can have a tremendously increased success rate if the appropriate imaging modality is used for complete tumor removal. Magnetic resonance imaging (MRI) provides excellent soft-tissue contrast and is the imaging modality of choice for brain tumor imaging. MRI combined with continuum soft robotics has immense potential to be the next major technological breakthrough in the field of brain cancer treatment. It would eliminate the concern of hand tremor and guarantee a more precise operation. One of the prototypes of MINIR-II, which can be classified as a continuum soft robot, consists of a snake-like body made of segments of rapid prototyped plastic springs. It provides improved dexterity with higher degrees of freedom and independent joint control. It is MRI-compatible, allowing surgeons to track and determine the real-time location of the robot relative to the brain tumor target. The robot is manufactured in a single piece using rapid prototyping technology at a very low cost to make it disposable after single use. MINIR-II has two DOFs at each segment with both joints controlled by two pairs of MRI-compatible SMA spring actuators.

9415-61, Session PSMon

Reconstruction of surfaces from planar contours through contour interpolation

Kyle R. Sunderland, Queen's Univ. (Canada); Boyeong Woo, Csaba Pinter, Gabor Fichtinger, Queen's Univ. (Canada)

PURPOSE: Segmented structures such as targets or organs at risk are typically stored as 2D contours contained on evenly spaced cross sectional images (slices). Contour interpolation algorithms are implemented in all radiation oncology treatment planning software to turn 2D contours into a 3D surface, however the results differ between algorithms, causing discrepancies in analysis. Our goal is to create an accurate and consistent contour interpolation algorithm, primarily motivated by radiation therapy research using the SlicerRT extension for the 3D Slicer platform. METHODS: The algorithm triangulates the mesh by minimizing the length of edges spanning the contours with dynamic programming. This paper discusses considerations in contour triangulation, such as correspondence, branching, tiling, and keyhole contours, as well as our methods for handling them. The first step in the algorithm is removing keyholes from contours. Correspondence is then found between contour layers and branching patterns are determined. The final step in the algorithm is triangulating the contours and sealing the external contours. RESULTS: The algorithm was tested on contours isolated from real computed tomography (CT) images. Some cases such as inner contours, rapid changes in contour size, and branching were found to be handled by the algorithm when encountered individually. There were some special cases however in which the simultaneous occurrence of several of these problems in the same location could cause the algorithm to produce suboptimal mesh. CONCLUSION: For most structures tested, we found the algorithm was able to generate a qualitatively good 3D mesh from the set of 2D contours.

9415-62, Session PSMon

Intraoperative on-the-fly organ-mosaicking for laparoscopic surgery

Sebastian Bodenstedt, Daniel Reichard, Stefan Suwelack, Karlsruher Institut für Technologie (Germany); Martin Wagner, Hannes Kenngott, Beat Peter Müller-Stich, Ruprecht-Karls-Univ. Heidelberg (Germany); Rüdiger Dillmann, Stefanie Speidel, Karlsruher Institut für Technologie (Germany)

The goal of computer-assisted surgery is to provide the surgeon with guidance during an intervention using augmented reality (AR). To display preoperative data correctly, soft tissue deformations that occur during surgery have to be taken into consideration. Optical laparoscopic sensors, such as stereo endoscopes, can produce a 3D reconstruction of single stereo frames for registration. Due to the small field of view and the homogeneous structure of tissue, reconstructing just a single frame in general will not provide enough detail to register and update preoperative data due to ambiguities. In this paper, we propose and evaluate a system that combines multiple smaller reconstructions from different points of view to segment and reconstruct a large model of an organ. By using GPU-based methods we achieve near real-time performance. We evaluated the system on an ex-vivo porcine liver (4.21mm ± 0.63) and on two synthetic silicone livers (3.64mm ± 0.31 and 1.89mm ± 0.19) using three different methods for estimating the camera pose (no tracking, optical tracking and a combination).

9415-63, Session PSMon

Application of single-image camera calibration for ultrasound augmented laparoscopic visualization

Xinyang Liu, Children's National Health System (United States); He Su, Children's National Health System (United States) and Tianjin Univ. (China); Sukryool Kang, Timothy D Kane, Raj Shekhar, Children's National Health System (United States)

Accurate calibration of laparoscopic cameras is essential for enabling many surgical visualization and navigation technologies, such as the ultrasound augmented visualization system that we have developed for laparoscopic surgery. In addition to accuracy and robustness, there is a practical need for a fast and easy camera calibration method that can be performed on demand in the operating room. Conventional camera calibration methods are not suitable for this task because they require acquisition of multiple images of a target pattern in its entirety to produce satisfactory result. In this work, we evaluate the performance of a single-image camera calibration method featuring automatic detection of corner points in the image, whether partial or complete, of a custom target pattern. Intrinsic camera parameters of a standard and a stereoscopic laparoscope were obtained and compared between the single-image camera calibration method and a well-accepted camera calibration method. Target registration error as a measure of calibration accuracy was also calculated to compare the two calibration methods with the use of an optical tracking system. Based on our experiments, the single-image camera calibration method yields consistent and accurate results, and thus, shows the promise of direct application in our augmented reality visualization system for laparoscopic surgery.

9415-64, Session PSMon

Towards real-time remote processing of laparoscopic video

Zahra Ronaghi, Edward Duffy, David M. Kwartowitz,

Clemson Univ. (United States)

Laparoscopy surgery is a surgical method, where surgeons insert a small video camera into the body to see patients' internal organs and small tools to perform surgical procedures. However, the benefit of small incisions brings a drawback of limited visualization of tissues. Image Guided Surgery (IGS) uses images to map subsurface structures and can reduce the limitations of laparoscopic surgery. One particular laparoscopic camera system of interest is the one used by the daVinci robotic surgical system. The video streams generate approximately 360 megabytes of data per second, demonstrating a trend towards increased data sizes in medicine, primarily due to higher-resolution video cameras and imaging equipment. Processing this data on a bedside PC has become challenging and a high performance computing (HPC) environment may not always be available at the point of care.

To process this data on remote HPC clusters at the typical 30 frames per second rate, it is required that each 11.9 MB video frame be processed by a server and returned within 1/30th of a second. The ability to acquire, process and visualize data in real-time is essential for performance of complex tasks as well as minimizing risk to the patient. As a result, utilizing high-speed networks to access computing clusters will lead to real-time medical image processing and improve surgical experiences by providing real-time augmented laparoscopic data. We aim to develop a medical video processing system using an OpenFlow software defined network that is capable of connecting to multiple remote medical facilities and HPC servers.

9415-65, Session PSMon

A novel method and workflow for stereotactic surgery with a mobile intraoperative CT imaging device

Senhu Li, Neal Clinthorne, Xoran Technologies, LLC (United States)

xCAT®, (Xoran Technologies, LLC., Ann Arbor, MI) is a CT imaging device that has been used for minimally invasive surgeries. Designed with flat panel and cone-beam imaging technique, it provides a fast, low-dose CT imaging alternative for diagnosis and examination purposes at hospitals. With its unique compact and mobile characteristics, it allows scanning inside crowded operating rooms (OR). The xCAT allows acquisition of images in the OR that show the most recent morphology during the procedure. This can potentially improve outcomes of surgical procedures such as deep brain stimulation (DBS), since brain displacement and deformation (brain shift) often occur between pre-operative imaging and electrode placement during surgery. However, the small gantry size of the compact scanner obstructs scanning of patients with stereotactic frames. In this study, we explored a novel method, in which we first utilized the xCAT to obtain CT images with fiducial markers, registered the stereotactic frame with those markers, and finally, target measurements were calculated and set up on the frame. The new procedure workflow provides a means to use CT images obtained inside of OR for stereotactic surgery and can be used in current intraoperative settings. Our phantom validation study in lab shows that the procedure workflow with this method is easy to conduct.

9415-67, Session PSMon

Sparse reconstruction of liver cirrhosis from monocular mini-laparoscopic sequences

J. Marek Marcinczak, Sven Painer, Rolf-Rainer Grigat, Technische Univ. Hamburg-Harburg (Germany)

Mini-laparoscopy is a technique which is used by clinicians to inspect the liver surface with ultra-thin laparoscopes. However, so far no quantitative measures based on mini-laparoscopic sequences are possible. This paper presents a Structure from Motion (SfM) based methodology to 3D

reconstruction of liver cirrhosis from mini-laparoscopic videos. The approach combines state-of-the-art tracking, pose estimation, outlier rejection and global optimization to obtain a sparse reconstruction of the cirrhotic liver surface. Specular reflection segmentation is included into the reconstruction framework to increase the robustness of the reconstruction. The presented approach is evaluated on 15 endoscopic sequences using three cirrhotic liver phantoms. The median reconstruction accuracy ranges from 0.3 mm to 1 mm.

9415-68, Session PSMon

Development and clinical application of surgical navigation system for laparoscopic hepatectomy

Yuichiro Hayashi, Tsuyoshi Igami, Tomoaki Hirose, Masato Nagino, Kensaku Mori, Nagoya Univ. (Japan)

This paper describes a surgical navigation system for laparoscopic surgery and its application to laparoscopic hepatectomy. The proposed surgical navigation system presents virtual laparoscopic views using a 3D positional tracker and preoperative CT images. We use an electromagnetic tracker for obtaining positional information of laparoscope and forceps. Point-pair matching registration method is performed for aligning coordinate systems between the tracker and the CT images. Virtual laparoscopic views corresponding to the laparoscope position are generated from the positional information, the registration results, and CT images using volume rendering method. We performed surgical navigation using the proposed system during laparoscopic hepatectomy for fourteen cases. The proposed system could generate virtual laparoscopic views in synchronization with the laparoscope position.

9415-69, Session PSMon

MR-TRUS registration based on subject-specific biomechanical model for image-guided prostate interventions

Xiaofeng Yang, Peter Rossi, Tomi Ogunleye, Ashesh Jani, Walter Curran, Tian Liu, Emory Univ. (United States)

The objective of this study is to develop a MR-TRUS prostate registration with a subject-specific biomechanical model, acquired from two US scans, to improve MR-targeted, US-guided prostate interventions (e.g., biopsy and radiotherapy) by incorporating the cancerous regions obtained from multiparametric MRI. The proposed registration method combines a novel subject-specific biomechanical model with a B-spline transformation to register the prostate gland of the MR image to the TRUS volume. The B-spline transformation is calculated by minimizing Euclidean distance between the normalized attribute vectors of landmarks on MR and TRUS prostate surfaces. The subject-specific biomechanical model is obtained through two US scans in which a 3D elasticity (strain) map of the prostate is generated. This biomechanical model is then used to constrain the B-spline-based transformation to predict and compensate for the internal prostate-gland deformation. This method is validated with a prostate-phantom experiment and a pilot study of 5 prostate-cancer patients. For the phantom study, the mean target registration error (TRE) was 1.29 mm. MR-TRUS registration was also successfully performed for 5 patients and the mean TRE was 1.71±0.25 mm. The proposed registration method may provide an accurate and robust means of estimating internal prostate-gland deformation, and is therefore well-suited to a number of MR-targeted, US-guided prostate interventions.

9415-70, Session PSMon

3D/2D image registration using weighted histogram of gradient directions

Soheil Ghafuriana, Ilker Hacihaliloglu, Dimitris N. Metaxas, Virak Tan, Kang Li, Rutgers, The State Univ. of New Jersey (United States)

Three dimensional (3D) to two dimensional (2D) image registration is crucial in many medical applications such as image-guided evaluation of musculoskeletal disorders. One of the key techniques is to estimate the 3D bone positions (translation and rotation) which maximize the similarity between the digitally reconstructed radiographs (DRRs) and the experimentally collected 2D fluoroscopic images using a registration method. This problem is computational-intensive due to a large search space and the complicated DRR generation process. Also, finding a similarity measure which converges to the global optimum instead of local optima adds to the challenge. To circumvent these issues, most existing registration methods need a manual initialization, which requires user interaction and is prone to human error. In this paper, we introduce a novel feature-based registration method using the weighted histogram of gradient directions of images. This method simplifies the computation by searching the parameter space (rotation and translation) sequentially rather than simultaneously. In our numeric simulation experiments, the proposed registration algorithm was able to achieve sub-millimeter and sub-degree accuracies. Moreover, our method is robust to the initial guess. It can tolerate up to ±90° rotation offset from the global optimal solution, which minimizes the need for human interaction to initialize the algorithm.

9415-71, Session PSMon

A metric for evaluation of deformable image registration

Akihiro Takemura, Kanazawa Univ. (Japan); Hironori Kojima, Shinichi Ueda, Naoki Isomura, Kimiya Noto, Kanazawa Univ. Hospital (Japan); Tomohiro Ikeda, Kanazawa Univ (Japan)

We propose a new metric, local uncertainty (LU), for the evaluation of deformable image registration (DIR) for dose accumulation in radiotherapy. LU measures the uncertainty of placement of each voxel in an image set after a DIR. The underlying concept of LU is that the distance between a focused voxel and a surrounding voxel on an image feature such as an edge is unchanged locally when the organ that includes these voxels is deformed. A candidate for the focused voxel after DIR can be calculated from three surrounding voxels and their distances. The positions of the candidates of the focused voxel calculated from several groups of any three surrounding voxels would vary. The variation of candidate positions indicates uncertainty of the focused voxel position. Thus, the standard deviation of candidate positions is treated as an LU value. The LU can be calculated in uniform signal regions. Assessment of DIR results in such regions is important for dose accumulation. The LU calculation was applied to a pair of computed tomography (CT) head and neck examinations after DIR. These CT examinations were for the initial radiotherapy planning and re-planning for a treatment course where the tumor underwent shrinkage during treatment. We generated an LU image showing high LU values in the shrinking tumor region and low LU values in undeformable bone. We propose the LU as a new metric for DIR.

9415-72, Session PSMon

An anatomically oriented breast model for MRI

Dominik Kutra, Martin Bergtholdt, Jöerg Sabczynski, Philips Research (Germany); Olaf Dössel, Karlsruher

Institut für Technologie (Germany); Thomas Buelow, Philips Research (Germany)

Breast cancer is the most common cancer in women in the western world. In breast cancer diagnosis and treatment, MRI is e.g. employed for the assessment of neo-adjuvant chemotherapy and lesion characterization.

Reading of a single three dimensional image or comparing a multitude of such images in a time series is a time consuming task. Radiological reporting is done manually by translating the spatial position of a finding in an image to a generic representation in the form of a breast diagram, outlining quadrants or clock positions. Currently, registration algorithms are employed to aid with the reading and interpretation of longitudinal studies by providing positional correspondence. To aid with the reporting of findings, knowledge about the breast anatomy has to be introduced to translate from patient specific positions to a generic representation. In our approach we fit a geometric primitive, the semi-super-ellipsoid to patient data. Anatomical knowledge is incorporated by fixing the tip of the super-ellipsoid to the mammilla position and constraining its center-point to a reference plane defined by landmarks on the sternum. A coordinate system is then constructed by linearly scaling the fitted super-ellipsoid, defining a unique set of parameters to each point in the image volume. By fitting such a coordinate system to a different image of the same patient, positional correspondence can be generated. We have validated our method on three pairs of baseline and follow-up scans (six breasts) that were acquired for the assessment of neo-adjuvant chemotherapy. On average, the location predicted and the actual location of manually set landmarks are within a distance of 6.0 mm. Our proposed method allows for automatic reporting simply by uniformly dividing the super-ellipsoid around its main axis. For the final paper we will include results of at least ten pairs of baseline and follow-up scans.

9415-73, Session PSMon

Surface-based registration of liver in ultrasound and CT

Ehsan Dehghan, KongKuo Lu, Pingkun Yan, Amir M. Tahmasebi, Philips Research North America (United States); Sheng Xu, Bradford J. Wood, Nadine Abi-Jaoudeh, Aradhana M. Venkatesan, National Institutes of Health (United States); Jochen Kruecker, Philips Research North America (United States)

Ultrasound imaging is an attractive modality for real-time image-guided interventions. Fusion of US imaging with a diagnostic imaging modality such as CT shows great potential in minimally invasive applications such as liver biopsy and ablation. However, significantly different representation of liver in US and CT turns this image fusion into a challenging task, in particular if some of the CT scans may be obtained without contrast agents. Blood vessels can serve as registration features only if contrast-enhanced CT is used and if the ultrasound image quality is sufficient to show some of the same vessels in the ultrasound image. Otherwise, registration needs to rely on a different image feature. The liver surface, including the diaphragm immediately adjacent to it, typically appears as a hyper-echoic region in the ultrasound image if the proper imaging window and depth setting are used.

The liver surface is also well visualized in both contrast and non-contrast CT scans, thus making the diaphragm or liver surface one of the few attractive common features for registration of US and CT. We propose a fusion method based on point-to-volume registration of liver surface segmented in CT to a processed electromagnetically (EM) tracked US volume. In this approach, first, the US image is pre-processed in order to enhance the liver surface features. In addition, non-imaging information from the EM-tracking system is used to initialize and constrain the registration process. We tested our algorithm in comparison with a manually corrected vessel-based registration method using 8 pairs of tracked US and contrast CT volumes. Our results show that if the US image acquisition is optimized for imaging of the diaphragm, high registration success rates are achievable.

9415-74, Session PSMon

Model-based deformable registration of MRI breast images with enhanced feature selection

Shadi Emami Abarghouei, McMaster Univ. (Canada); Bahram Marami, Robarts Research Institute (Canada); Shahin Sirouspour, McMaster Univ. (Canada)

A model-based non-rigid method for registration of single-modality magnetic resonance images of compressed and uncompressed breast tissue in breast cancer diagnostic/interventional imaging is presented. First, based on segmented pre-operative images, a deformation model of the breast tissue is developed and discretized in the spatial domain using the method of finite element. The compression of the pre-operative image is modeled by applying smooth normal forces on the surface of the breast where compression plates are placed. Image registration is accomplished by solving an optimization problem. The cost function is a similarity measure between the deformed preoperative image and intraoperative image computed at some control points and the decision variables are the tissue interaction forces. An extension of the Speeded Up Robust Features to 3D is employed to extract control feature points. Sum of squared differences of the image intensities at the control points is the similarity measure minimized in the optimization. This algorithm has been successfully applied to clinical breast MR images.

9415-75, Session PSMon

Smooth extrapolation of unknown anatomy via statistical shape models

Robert B. Grupp Jr., Hsin-Hong Chiang, Yoshito Otake, Ryan J. Murphy, Chad R. Gordon, Mehran Armand, Russell H. Taylor, Johns Hopkins Univ. (United States)

Several methods to perform extrapolation of unknown anatomy are evaluated. The primary application is to enhance surgical procedures that use partial medical images or medical images of incomplete anatomy. Periacetabular Osteotomy and Total Face-Jaw-Teeth Transplant are two such procedures. From CT data of 36 skulls and 21 mandibles, separate Statistical Shape Models of the skull and mandible were created. Using the Statistical Shape Models, incomplete surfaces are projected to obtain a complete surface estimate. This surface estimate exhibits non-zero error in regions where the true surface is known; it is desirable to keep the true surface and seamlessly merge the estimated unknown surface. Existing extrapolation techniques result in non-smooth transitions from the true surface to the estimated surface, resulting in additional error and a less aesthetically pleasing result. The three extrapolation techniques evaluated are: copying and pasting of the surface estimate (non-smooth baseline), a feathering between the patient surface and surface estimate, and an estimate generated via a Thin Plate Spline trained from displacements between the surface estimate and corresponding vertices of the known patient surface. Feathering and Thin Plate Spline approaches both yield smooth transitions. However, feathering corrupts known vertex values. Leave-one-out analyses are conducted, with 5% to 50% of known anatomy removed from the left-out patient and estimated via the proposed approaches. The Thin Plate Spline approach yields smaller errors than the other two approaches, with an average vertex error improvement of 1.46 mm and 1.37 mm, for the skull and mandible respectively, over the baseline approach.

9415-76, Session PSMon

Collision detection and modeling of rigid and deformable objects in laparoscopic simulator

Mary-Clare C. Dy, Ritsumeikan Univ. (Japan) and Shiga Univ. of Medical Science (Japan); Kazuyoshi Tagawa, Hiromi T. Tanaka, Ritsumeikan Univ. (Japan); Masaru Komori, Shiga Univ. of Medical Science (Japan)

Laparoscopic simulators are viable alternatives for surgical training, instead of using box trainers. Haptic devices can also be incorporated with virtual reality simulators to provide additional cues to the users. However, to provide a realistic feedback, the haptic device must be updated by 1kHz. This means the computation of rigid (surgical tools) and deformable (organs, and tissues) objects interaction must be at par with the refresh rate of the haptic devices. Our current laparoscopic simulator is able to detect the collision between a point on the tool tip, and on the organ surfaces, in which Geomagic™ Touch devices are attached on actual tool tips for realistic tool manipulation. The triangular-mesh organ model is rendered using a mass spring deformation model, or finite element method-based models. In this paper, we propose a method to improve the collision detection scheme, and speed up the organ deformation reaction. Instead of just one contact point, we will extend possible collision points up to the tool rods. The tool rod will be based on a line segment, and will be marked at first with sparsely distributed points, each with their own normal direction. The organs and tissues will be represented using a grid to provide vertex positions. Possible contact points between the tool and organ will be determined using hierarchical binary approach. The grid also provides information about adjacent tetrahedrons thus computing the consequent deformation of affected tetrahedrons will be faster. In addition, a predictive collision detection method1 can be used to decrease tool-to-organ interpenetration.

9415-77, Session PSMon

Surgical instrument similarity metrics and tray analysis for multi-sensor instrument identification

Bernhard Glaser, Tobias Schellenberg, Stefan Franke, Stefan Dänzer, Thomas Neumuth, ICCAS Innovation Ctr. Computer Assisted Surgery (Germany)

A robust identification of the instrument currently used by the surgeon is crucial for the automatic modeling and analysis of surgical procedures. Various approaches for intra-operative surgical instrument identification have been presented, mostly based on RFID detection or endoscopic video analysis. A novel approach is to identify the instruments on the instrument table of the scrub nurse with a combination of video and weight information. In a previous article, we successfully followed this approach and applied it to multiple instances of an ENT procedure and the used surgical tray. In this article, we present a metric for the suitability of the instruments of a surgical tray for identification by video and weight analysis and apply it to twelve trays of four different surgical domains (abdominal surgery, neurosurgery, orthopedics and urology). The used trays were digitalized at the central sterile services department of the University Hospital of Leipzig, Germany. The results illustrate that surgical trays differ in their suitability for the approach. In general, additional weight information can significantly contribute to the successful identification of surgical instruments. Additionally, for ten different surgical instruments ten exemplars of each instrument were tested for their weight differences. The samples indicate high weight variability in instruments with identical brand and model number. The results present a new metric for approaches aiming towards intraoperative surgical instrument detection and imply consequences for algorithms exploiting video and weight information for identification purposes.

9415-78, Session PSMon

Which pivot calibration?

Ziv R. Yaniv, Children's National Health System (United States)

Estimating the location of a tracked tool's tip relative to its Dynamic Reference Frame (DRF) and localizing a specific point in a tracking system's coordinate frame are fundamental tasks in image-guided interventions. The most common approach to estimating these values is by pivoting a tool around a fixed point. The transformations from the tracking system's frame to the tool's DRF are the input. The output is the translation from the DRF to the tool's tip and the translation from the tracker's frame to the pivoting point. While the input and output are unique, there are multiple mathematical formulations for performing this estimation task. The question is, are these formulations equivalent in terms of precision and accuracy? In this work we empirically evaluate three common formulations, a geometry based sphere fitting formulation and two algebraic formulations. Our initial evaluation shows that the algebraic formulations yield estimates that are more precise and accurate than the sphere fitting formulation. Using the Vicra optical tracking system from Northern Digital Inc., we observed that the algebraic (sphere fitting) approaches have a precision of less than 0.4(0.7)mm localizing the pivoting point relative to the tracked DRF, and yield fiducial registration accuracy of less than 0.35(0.4)mm when registering a precisely constructed divot phantom to the localized points in the tracking system's frame.

9415-79, Session PSMon

A model-free method for annotating on vascular structure in volume rendered images

Wei He, Yanfang Li, Weili Shi, Yu Miao, Fei He, Fei Yan, Huamin Yang, Changchun Univ. of Science and Technology (China); Huimao ZHANG, The First Hospital of Jilin University (China); Kensaku Mori, Nagoya Univ. (Japan); Zhengang Jiang, Changchun Univ. of Science and Technology (China)

The precise annotation of vessel is desired in computer-assisted systems to help surgeons identify each vessel branch. A method has been reported that annotates vessels on volume rendered images by rendering their names on them using a two-pass rendering process. In the reported method, however, cylinder surface models of the vessels should be generated to be used writing vessels names. In fact, vessels are not actual cylinders, so the surfaces of the vessels cannot be simulated by such models accurately. This paper presents a model-free method for annotating vessels on volume rendered images by rendering their names on them using the two-pass rendering process: surface rendering and volume rendering. In the surface rendering process, docking points of vessel names are estimated by using such properties as centerlines, running directions, and vessel regions which are obtained in preprocess. Then the vessel names are pasted on the vessel surfaces at the docking points. In the volume rendering process, volume image is rendered using a fast volume rendering algorithm with depth buffer of image rendered in the surface rendering process. Finally, those rendered images are blended into an image as a result. In order to confirm the proposed method, a visualizing system for the automated annotation of abdominal arteries is performed. The experimental results show that vessel names can be drawn on the corresponding vessel in the volume rendered images correctly. The proposed method has enormous potential to be adopted to annotate other organs which cannot be modeled using regular geometrical surface.

9415-80, Session PSMon

Line fiducial material and thickness considerations for ultrasound calibration

Golafsoun Ameri, A. Jonathan McLeod, John S. H. Baxter, Elvis C. S. Chen, Terry M. Peters, Robarts Research Institute (Canada)

Ultrasound calibration is a necessary procedure in image-guided interventions relating the position of the anatomical structure on the ultrasound image to a common coordinate system such as a 3D virtual reality environment where other surgical tools can be found. Accuracy of ultrasound calibration fundamentally affects the total accuracy of the interventional guidance system. Many ultrasound calibration procedures have been proposed based on a variety of materials and geometries. These differences lead to differences in representation of the phantom on the ultrasound image and subsequently affect the ability to be accurately and automatically segmented. In this paper, an evaluation of a variety of calibration phantoms with different geometry and material properties for both Z-bar and phantomless calibration is performed. The phantoms are automatically segmented from the ultrasound images using an ellipse fitting algorithm, which are subsequently used for calibration. We evaluate calibration accuracy for these procedures. We hypothesize that larger diameter phantoms with lower echogenicity are more accurately segmented in ultrasound images in comparison to highly reflective thin phantoms. We also hypothesize that a more accurate segmentation of the phantom leads to a lower fiducial localization error, which ultimately results in low target registration error. This would have a profound effect on calibration procedures and the feasibility of different calibration procedures in the context of image-guided procedures.

9415-81, Session PSMon

Live ultrasound volume reconstruction using scout scanning

Amelie Meyer, Lab. for Percutaneous Surgery (Canada) and Univ. de Strasbourg (France); Andras Lasso, Tamas Ungi, Gabor Fichtinger, Lab. for Percutaneous Surgery (Canada)

PURPOSE: Ultrasound-guided interventions often necessitate scanning of deep-seated anatomical structures that may be hard to visualize. Visualization can be improved using reconstructed 3D ultrasound volumes, but often there is not enough time for high resolution reconstruction of a large anatomical area during clinical interventions. We propose a two-stage scanning method allowing the user to perform quick low resolution scouting followed by high resolution live volume reconstruction. METHODS: Scout scanning is accomplished by stacking 2D tracked ultrasound images into a low resolution volume. Then, within a region of interest defined in the scout scan, live volume reconstruction is performed by continuous scanning until sufficient image density is achieved. We implemented the workflow as a module of the open-source 3D Slicer application, within the SlicerIGT extension and building on the PLUS toolkit. RESULTS: Scout scanning is performed in a few seconds using 3 mm spacing to allow region of interest definition. Live reconstruction parameters are set to provide good quality image (0.5 mm spacing, hole filling enabled) and feedback is given during live scanning by regularly updated volumes. CONCLUSION: Use of scout scanning may allow the physician to identify anatomical structures. Subsequent live volume reconstruction in a region of interest may assist in procedures such as needle interventions.

9415-82, Session PSMon

Benchmarking of state-of-the-art needle detection algorithms in 3D ultrasound data volumes

Arash Pourtaherian, Svitlana Zinger, Peter H. N. de With, Technische Univ. Eindhoven (Netherlands); Hendrikus H. M. Korsten, Catharina-ziekenhuis (Netherlands) and Technische Univ. Eindhoven (Netherlands); Nenad Mihajlovic, Philips Research Nederland B.V. (Netherlands)

Ultrasound-guided needle interventions are widely practiced in medical diagnostics and therapy, i.e. for biopsy guidance, regional anesthesia or for brachytherapy. A needle guidance using 2D ultrasound can be very challenging due to the poor needle visibility and the limited field of view. As 3D ultrasound transducers are becoming more widely used, needle guidance can be improved and simplified with appropriate computer-aided analyses. In this paper, we compare two state-of-the-art 3D needle detection techniques; one is based on line filtering and another on Gabor transformation. Both algorithms utilize supervised classification to pre-select candidate needle voxels in the volume and then fit a model of the needle on the selected voxels. Major differences between the two approaches that we study are in extracting the feature vectors for classification and selecting the fit criterion. We evaluate the performance of the two techniques in several ex-vivo situations of different complexities, containing three needle types with different insertion angles. Our evaluation is based on measuring the distance and angle between the ground-truth needle axis and the detected needle axis. Ground-truth needles are annotated manually in each volume and their 3D parameters are extracted. Benchmarking results show better ability of the Gabor features in distinguishing the needle voxels. Moreover, we can see that the complete chain of the Gabor-based method outperforms the line filtering in accuracy and stability of the detection results.

9415-84, Session PSMon

B-Mode ultrasound pose recovery via surgical fiducial segmentation and tracking

Alessandro Asoni, Michael Ketcha, Nathanael Kuo, Devin Coon, Jerry L. Prince, Lei Chen, Emad M Boctor, Johns Hopkins Univ. (United States)

DESCRIPTION OF PURPOSE: In plastic reconstructive, vascular and transplant surgeries, blood vessels must be connected together. However, all anastomoses can form a blood clot in the few days that follow the surgery. In particular, free tissue transfers for reconstructive surgery have a high rate of thrombosis (5-15%). If the clot is detected in time, the patient returns to surgery and the clot is removed to save the reconstruction. However, approximately half of the time it is too late and the tissue undergoes necrosis [1, 2]. Doppler ultrasound is an effective method to serially monitor flow across the vessels, but it requires expertise to navigate to and identify the surgical site repeatedly. We sought to develop a system to simplify this process.

RESULTS: We combined the following three components into one system: full frame detection, tracking, and pose estimation. The full frame detection finds the six fiducial points. These points get passed to the tracking algorithm and then to the pose estimation algorithm. Currently tracking helps in smoothing out detection errors by ensuring that the detected points lie in the feasible space of the fiducial shape defined by the principal components. The pose estimation takes the six points, and determines the imaging plane on the model that best fits the cross-section seen in the image.

The NCC for tracking is not complete nor does the system function in real-time, but we intend to fix these weaknesses by the time of manuscript submission. On average, it took approximately .76 seconds to make all

calculations between frames. The state covariance from the Kalman Filter was used to determine how successful was the point tracking to determine the current pose. If the trace of the state covariance was above a predetermined threshold, we supply visual feedback indicating that the current estimated pose is unlikely to be correct.

CONCLUSIONS: In this paper, we present ultrasound B-mode analysis software for the detection of blood clots in anastomoses. The software particularly includes a point detector algorithm to detect a fiducial in a single frame and a corresponding point tracker algorithm to track the fiducial over multiple frames. Combining these algorithms with a pose estimation algorithm allows the user to follow the position of the probe with respect to the marker in order to consistently locate the site of anastomoses over multiple instances of monitoring. Such software therefore acts as a precursor for Doppler measurements of blood flow, which would detect blood clots in skin flaps otherwise destined for necrosis. In the end, these algorithms improve patient care while saving time and money.

REFERENCES

[1] Nakatsuka T et. al. (2003). Analytic Review of 2372 Free Flap Transfers for Reconstruction Following Cancer Resection. Journal of Reconstructive Microsurgery, 19(6): 363-368.

[2] Bui DT et al. (2007). Free Flap Reexploration; Indications, Treatment, and Outcomes in 1,193 Free Flaps. J of Plastics and Reconstructive Surgery, 119(7): 2092-2100.

[3] A. Myronenko and X.B. Song, Point-Set Registration: Coherent Point Drift, IEEE Trans. Pattern Analysis and Machine Intelligence, vol. 32, no. 12, pp. 2262-2275, Dec. 2010.

[4] Welch, G., and G. Bishop (1995), An introduction to the Kalman Filter. Technical Report TR 95-041, University of North Carolina, Department of Computer Science

[5] Jolliffe, Ian. Principal component analysis. John Wiley & Sons, Ltd, 2005.

9415-85, Session PSMon

Validation of percutaneous puncture trajectory during renal access using 4D ultrasound reconstruction

Pedro L. Rodrigues, ICVS/3B's - PT Government Associate Lab. (Portugal) and Algoritmi Ctr., Univ. do Minho (Portugal) and DIGARC – Polytechnic Institute of Cávado and Ave (Portugal); Nuno F. Rodrigues, Algoritmi Ctr., School of Engineering, Univ. do Minho (Portugal) and DIGARC – Polytechnic Institute of Cávado and Ave (Portugal) and ICVS/3B's - PT Government Associate Lab. (Portugal); Jaime C. Fonseca, Algoritmi Ctr., School of Engineering, Univ. do Minho (Portugal); João L. Vilaça, DIGARC – Polytechnic Institute of Cávado and Ave (Portugal) and ICVS/3B's - PT Government Associate Lab. (Portugal) and Univ. do Minho (Portugal)

Background: An accurate percutaneous puncture is essential for disintegration and removal of renal stones. Although this procedure has proven to be safe, some organs surrounding the renal target might be accidentally perforated. This work describes a new intraoperative framework where tracked surgical tools are superimposed within 4D ultrasound imaging for security assessment of the percutaneous puncture trajectory (PPT).

Methods: A PPT is first generated from the skin puncture site towards an anatomical target, using the information retrieved by electromagnetic motion tracking sensors coupled to surgical tools. Then, 2D ultrasound images acquired with a tracked probe are used to reconstruct a 4D ultrasound around the PPT under GPU processing. Volume hole-filling was performed in different processing time intervals by a tri-linear interpolation method. At spaced time intervals, the volume of the anatomical structures was segmented to ascertain if any vital structure is in between PPT and

might compromise the surgical success. To enhance the volume visualization of the reconstructed structures, different render transfer functions were used.

Results: Real-time US volume reconstruction and rendering with more than 25 frames/s was only possible when rendering only three orthogonal slice views. When using the whole reconstructed volume one achieved 8-15 frames/s. 3 frames/s were reached when one introduce the segmentation and detection if some structure intersected the PPT.

Conclusions: The proposed framework creates a virtual and intuitive platform that can be used to identify and validate a PPT to safely and accurately perform the puncture in percutaneous nephrolithotomy.

9415-86, Session PSMon

3D printed surface mould applicator for high-dose-rate brachytherapy

Mark W. Schumacher, Lab. for Percutaneous Surgery (Canada) and Queen's Univ. (Canada); Andras Lasso, Lab. for Percutaneous Surgery (Canada); Joshi Chandra, Conrad B. Falkson, L. John Schreiner, Kingston General Hospital (Canada); Gabor Fichtinger, Lab. for Percutaneous Surgery (Canada)

PURPOSE: Develop a planning and placement method of high-dose-rate brachytherapy catheters for treatment of superficial tumors. Creation of current wax models is a difficult and time consuming process. The irradiation plan can only be computed post-construction and requires a second CT scan. In case no satisfactory dose plan can be created, the mould is discarded and the process is repeated. METHODS: We developed a method to design and manufacture moulds that guarantee to yield satisfactory dosimetry. A 3D-printed mould with channels for the catheters designed from the patient's CT and mounted on a patient-specific thermoplastic mesh mask. The mould planner is implemented as an open-source module in the 3D Slicer platform. RESULTS: Series of test moulds were created to accommodate standard brachytherapy catheters of 1.70mm diameter. A calibration object was used to conclude that tunnels with a diameter of 2.25mm, minimum 12mm radius of curvature, and 1.0mm open channel gave the best fit for this printer/catheter combination. Moulds were created from the CT scan of thermoplastic mesh masks of actual patients. CONCLUSION: The patient-specific moulds are currently being tested in the Kingston General Hospital, the resulting dosimetry is being compared with treatment plans and dosimetry achieved with conventional wax moulds. Quantitative dosimetry results will be available at the conference and the final paper.

9415-87, Session PSMon

Method for evaluation of predictive models of microwave ablation via post-procedural clinical imaging

Jarrod A. Collins, Vanderbilt Univ. (United States); Dan Brown, Vanderbilt Univ. Medical Ctr. (United States); T. Peter Kingham, William R. Jarnagin, Memorial Sloan-Kettering Cancer Ctr. (United States); Michael I. Miga, Logan W. Clements, Vanderbilt Univ. (United States)

Development of a clinically accurate predictive model of microwave ablation (MWA) procedures would represent a significant advancement and facilitate an implementation of patient-specific treatment planning to achieve optimal probe placement and ablation outcomes. While studies have been performed to evaluate predictive models of MWA, the ability to quantify the performance of predictive models via clinical data has been limited to comparing geometric measurements of the predicted and actual ablation zones. The accuracy of placement, as determined by the

degree of spatial overlap between ablation zones, has not been achieved. In order to overcome this limitation, a method of evaluation is proposed where the actual location of the MWA antenna is tracked and recorded during the procedure via a surgical navigation system. Predictive models of the MWA are then computed using the known position of the antenna within the preoperative image space. Two different predictive MWA models were used for the preliminary evaluation of the proposed method: (1) a geometric model based on the labeling associated with the ablation antenna and (2) a 3-D finite element method based computational model of MWA using COMSOL. Given the follow-up tomographic images that are acquired at approximately 30 days after the procedure, a 3-D surface model of the necrotic zone was generated to represent the true ablation zone. A quantification of the overlap between the predicted ablation zones and the true ablation zone was performed after a rigid registration was computed between the pre- and post-procedural tomograms.

9415-88, Session PSMon

Needle position estimation from sub-sampled k-space data for MRI-guided interventions

Sebastian Schmitt, Westfälische Hochschule (Germany); Morwan Choli, MR:comp GmbH (Germany); Heinrich-Martin Overhoff, Westfälische Hochschule (Germany)

MRI-guided interventions have gained much interest. They profit from intervention synchronous data acquisition and image visualization. Due to long data acquisition durations, ergonomic limitations may occur. For a trueFISP MRI-data acquisition sequence, a time sparing subsampling strategy has been developed that is adapted to amagnetic needle detection.

A symmetrical and contrast rich susceptibility needle artifact, i.e. an approximately rectangular gray scale profile is assumed. The 1-D-Fourier Transformed of a rectangular function is a sinc-function. Its periodicity is exploited by sampling only along a few orthogonal trajectories in k-space. Because a needle moves during intervention, its tip region resembles a rectangle in a time-difference image that is reconstructed from such subsampled k-spaces acquired at different time stamps.

In four exemplary phantom experiments, a needle was pushed forward along a reference trajectory, which was determined from a needle holders geometric parameters and an expert. In addition, the trajectory of the needle tip was estimated by the method described above. Only ca. 4 to 5 % of the entire k-space data was used for needle tip estimation. The misalignment of needle orientation and needle tip position, i.e. the differences between reference and estimated values, is small and even in its worst case less than 2 mm.

The results show that the method is applicable under nearly real conditions. Next steps are addressed to the validation of the method for clinical data.

9415-89, Session PSMon

Intraoperative assessment and visualization of electromagnetic tracking error

Vinyas Harish, Tamas Ungi, Andras Lasso, Lab. for Percutaneous Surgery (Canada); Andrew MacDonald, Lab. for Percutaneous Surgery (Canada) and Queen's Univ. (Canada); Sulaiman Nanji, Queen's Univ. (Canada); Gabor Fichtinger, Lab. for Percutaneous Surgery (Canada)

PURPOSE: It is well understood that electromagnetic tracking is prone to error. Assessment and visualization of the tracking error should take place in the operating room while the navigation is in use with minimal interference with the clinical procedure. We achieved this ideal in an open-source software implementation in a plug and play manner, without requiring

programming from the user. METHODS: We use ground truth optical tracking. An electromagnetic sensor and optical markers are mounted onto a stylus device, pivot calibrated for both trackers. Electromagnetic tracking error is defined as the difference in tool tip position between electromagnetic and optical readings. Multiple measurements are interpolated into the thin-plate B-spline transform visualized in real time using a core 3D Slicer function. All tracked devices are used in a plug and play manner through the open-source SlicerIGT and PLUS extensions of the 3D Slicer platform. RESULTS: Tracking error was measured to assess reproducibility of the method, both with and without placing metal objects in the workspace. Results from exhaustive grid sampling and freehand sampling were similar, indicating that a quick freehand sampling is sufficient to detect unexpected or excessive field distortion in the operating room. CONCLUSION: The system is available as a plug-in for the 3D Slicer platform. Results demonstrate potential for visualizing electromagnetic tracking error in real time for intraoperative environments in safety and feasibility clinical trials in image-guided interventions.

9415-90, Session PSMon

Combining marker-less patient setup and respiratory motion monitoring using Kinect

Fatemeh Tahavori, Univ. of Surrey (United Kingdom); Elizabeth Adams, Marianne Dabbs, Tom Jordan, Royal Surrey County Hospital, NHS (United Kingdom); Phil Evans, Kevin Wells, Univ. of Surrey (United Kingdom)

Patient misalignment/motion can be a significant source of error within external beam radiotherapy, leading to unwanted dose to healthy tissues, and sub-optimal dose to the target tissue. Such inadvertent displacement or motion of the target volume may be caused by treatment set-up error, respiratory motion or involuntary movement potentially decreasing therapeutic benefit. The conventional approach to managing abdominal-thoracic patient set-up is via skin markers (tattoos) and laser-based alignment. Internal alignment of the target volume with the treatment plan can be achieved using Deep Inspiration Breath Hold (DIBH) in conjunction with marker-based respiratory motion monitoring.

We propose a marker-less single system solution to both patient set-up and respiratory motion management based on low cost 3D depth camera technology (such as the MS Kinect). In this new work we asses this approach in a study group of ten volunteer subjects. Ten separate treatment "fractions" or set-ups are compared for each subject, undertaken using conventional laser-based alignment and with Kinect depth data registered using an a?ne registration. Microsoft Kinect is also compared with the well-known RPM system for respiratory motion management in terms of monitoring free-breathing and DIBH to a pre-determined threshold under clinical guidance. Preliminary results suggest that Kinect is able to produce mm-level surface alignment, and a more accurate response to DIBH respiratory motion management. Such an approach may also yield significant benefits in terms of patient throughput.

9415-91, Session PSMon

Quantification of intraventricular blood clot in MR-guided focused ultrasound surgery

Margaret A. Hess, Queen's Univ. (Canada) and The Hospital for Sick Children (SickKids) (Canada); Thomas Looi, The Hospital for Sick Children (SickKids) (Canada); Andras Lasso, Gabor Fichtinger, Queen's Univ. (Canada); James Drake, The Hospital for Sick Children (SickKids) (Canada)

Intraventricular hemorrhage (IVH) is a significant problem for nearly 15% of preterm infants. It can lead to ventricular dilation and cognitive impairment.

To ablate IVH clots, MR-guided focused ultrasound surgery (MRgFUS) is investigated. This procedure requires accurate, fast and consistent quantification of changes in ventricle and clot volumes. METHODS: We developed a semi-autonomous segmentation (SAS) algorithm for measuring changes in the ventricle and clot volumes. The SAS workflow uses registration, threshold, and region growing algorithms to yield contour and volume information. Images are normalized, and then ventricle and clot masks are registered to the images. A label created by thresholding acts as the seeds for region growing, and the masks mark the background. SAS was evaluated on an IVH porcine model. SAS was compared to ground truth manual segmentation (MS) for accuracy, efficiency, and consistency. RESULTS: Accuracy was determined by comparing clot and ventricle volumes produced by SAS and MS, and comparing contours by calculating 95% Hausdorff distances between the two labels. In Two-One-Sided Test, SAS and MS were found to be significantly equivalent (p < 0.01). SAS on average was found to be 15 times faster than MS (p < 0.01). Consistency was determined by repeated segmentation of the same image by both SAS and manual methods, SAS being significantly more consistent than MS (p < 0.05). CONCLUSION: SAS is a viable method to quantify the IVH clot and the lateral brain ventricles and it is serving in a large-scale porcine study of MRgFUS treatment of IVH clot lysis.

9415-92, Session PSMon

Targeting of deep-brain structures in nonhuman primates using MR and CT Images

Antong Chen, Catherine D. G. Hines, Belma Dogdas, Merck & Co., Inc. (United States); Ashely Bone, Kenneth Lodge, Stacey O'Malley, Brett Connolly, Christopher T. Winkelmann, Ansuman Bagchi, Laura S. Lubbers, Jason M. Uslaner, Colena Johnson, John Renger, Merck & Co Inc (United States); Hatim Zariwala, Merck & Co., Inc. (United States)

In vivo gene delivery in central nervous systems of nonhuman primates (NHP) is an important approach for gene therapy and animal model development of human disease. This requires precise stereotactic targeting to brain structures to achieve a more accurate delivery of genetic probes. However, even with the assistance from multi-modality 3D imaging techniques (MR and CT), the precision of the targeting is often challenging due to difficulties in identification of small and deep brain structures, e.g Nucleus Basalis of Meynert (NBM), which often lack clear boundaries to supporting anatomical landmarks e.g. its surrounding white matter. Here we demonstrate a 3D-imaging-based intracranial stereotactic approach applied toward reproducible intracranial targeting of bilateral NBM of rhesus monkeys. For targeting NBM we discuss the feasibility of an atlas-based automatic approach: Delineated originally on a high resolution 3D histology-MR atlas set, NBM could be located on the MR image of the monkey through affine and nonrigid registrations. The automatic targeting of NBM was compared with the targeting conducted manually by an experienced neuroanatomist. Based on the targeting, the trajectories and entry points for delivering the genetic probes to the targets could then be established on the CT images of the monkeys after rigid registration. The accuracy of the targeting was assessed quantitatively by comparison between NBM locations obtained automatically and manually, and finally demonstrated qualitatively on cryostat sections through the monkey brain with Evan Blue infusion.

9415-93, Session PSMon

Analysis of left atrial respiratory and cardiac motion for cardiac ablation therapy

Maryam E. Rettmann, David R. Holmes III, Susan B. Johnson, Helge I. Lehmann, Richard A. Robb, Douglas L. Packer, Mayo Clinic (United States)

Cardiac ablation therapy is often guided by models built from preoperative CT or MRI scans. One of the challenges in guiding a procedure from a preoperative model is properly synching the preoperative models with cardiac and respiratory motion through computational motion models. In this paper, we describe a methodology for evaluating cardiac and respiratory motion in the left atrium and pulmonary veins of a beating canine heart. Cardiac catheters were used to place metal clips in the left atrium and pulmonary veins of a canine under fluoroscopic and ultrasound guidance and a contrast-enhanced, 64-slice multi-detector CT scan was collected with the clips in place. Each clip was segmented from the CT scan at each of the five phases of the cardiac cycle at both end-inspiration and end- expiration. The centroid of each segmented clip was computed and used to evaluate both cardiac and respiratory motion of the left atrium. When averaged across the four clips, the total mean cardiac mean cardiac motion at end-expiration was 5.7 +/- 2.5 mm and 4.4 +/- 1.5 mm at end-inspiration. Results of this work will be valuable for both quantification of left atrial motion as well as validation of computational motion models.

9415-94, Session PSMon

Register cardiac fiber orientations from 3D DTI volume to 2D ultrasound image of rat hearts

Xulei Qin, Silun Wang, Ming Shen, Xiaodong Zhang, Emory Univ. (United States); Stamatios Lerakis, Emory Univ (United States); Mary B. Wagner, Baowei Fei, Emory Univ. (United States)

2D ultrasound is one of the most routine test methods for the diagnosis of cardiac diseases. However, it only supplies the geometric and structural information of the myocardium. In order to supply more detailed microstructure information of the myocardium, this paper proposes a registration method to map cardiac fiber orientations from 3D diffusion tensor imaging (DTI) volume to the 2D ultrasound image. It utilizes a 2D/3D intensity based registration procedure including rigid, log-demons, and affine transformations to search the best similar slice from the template volume. After that, the cardiac fiber orientations are mapped to the 2D ultrasound image via fiber relocations and reorientations. This method was validated by six images of rat hearts ex vivo. The evaluation results indicated that the final Dice similarity coefficient (DSC) achieved more than 90% after geometric registrations; and the inclination angle errors (IAE) between the mapped fiber orientations and the gold standards were less than 15 degree. This method could help cardiologists to understand the cardiac physiology better and also has the potential to supply more information for diagnosis of cardiac diseases.

9415-95, Session PSMon

Simulated evaluation of an intraoperative surface modeling method for catheter ablation by a real phantom simulation experiment

Deyu Sun, Maryam E. Rettmann, Douglas L. Packer, Mayo Clinic (United States); Richard A. Robb, Mayo Clinic College of Medicine (United States); David R. Holmes III, Mayo Clinic (United States)

In this work, we propose a phantom experiment method to quantitatively evaluate an intraoperative left-atrial modeling update method. In prior work, we proposed an update procedure which updates the preoperative surface model with information from real-time tracked 2D ultrasound. Prior studies did not evaluate the reconstruction using an anthropomorphic phantom.

In this approach, a silicone heart phantom (based on a high resolution human atrial surface model reconstructed from CT images) was made as simulated atriums. A surface model of the left atrium of the phantom was deformed by a morphological operation – simulating the shape difference caused by organ deformation between pre-operative scanning and intra-operative guidance. During the simulated procedure, a tracked ultrasound catheter was inserted into right atrial phantom – scanning the left atrial phantom in a manner mimicking the cardiac ablation procedure. By merging the preoperative model and the intraoperative ultrasound images, an intraoperative left atrial model was reconstructed. According to results, the reconstruction error of the modeling method is smaller than the initial geometric difference caused by organ deformation. As the area of the left atrial phantom scanned by ultrasound increases, the reconstruction error of the intraoperative surface model decreases. The study validated the efficacy of the modeling method.

Conference 9416: Image Perception, Observer Performance, and Technology Assessment

Wednesday - Thursday 25–26 February 2015

Part of Proceedings of SPIE Vol. 9416 Medical Imaging 2015: Image Perception, Observer Performance, and Technology Assessment

9416-1, Session 1

I am a breast imager; you are a visual scientist. Let's dance and make a better a Radiologist. *(Keynote Presentation)*

Dianne Georgian-Smith, Brigham and Women's Hospital (United States)

Twenty-five years ago, Dr Georgian-Smith completed a fellowship in Breast Imaging, and was looking for a job as a general radiologist. Through an unforeseen series of events, she stayed on staff at University of Cincinnati (U.C.) and never left academia. She teamed with her U.C. colleague, Dr Bill Shiels D.O., who had invented the 'turkey breast model,' to learn and teach the hand-eye coordination of interventional ultrasound. This model carried her around the world. More importantly, her interest in education blossomed. Her next move was to University of Washington in Seattle in the mid-1990's. She began to ask, 'how do I see the finding 'architectural distortion' and why do others not see it? How can I teach what I see?.' It was not until a decade later when mammography became digital that these questions could be studied. The serendipitous meeting at the American Board of Radiology Oral Examination of the Irish perception investigators, Drs Brennan, McEntee, and Ryan, set up the team for collaboration. This work was supported by an RSNA Educational seed grant and was presented at RSNA in Chicago in 2011. What's next? She is determined to see the integration of the basic science of visual perception with the integration of clinical Radiology curriculum. The time has come for our fields to work in concert to make a better radiologist.

9416-2, Session 1

Incorporating breast tomosynthesis into radiology residency: Does trainee experience in breast imaging translate into improved performance with the new modality?

Lars J. Grimm, Duke Univ. (United States); Jing Zhang, Duke Univ. Medical Ctr. (United States); Karen Johnson, Duke Univ. (United States); Joseph Y. Lo, Duke Univ. School of Medicine (United States); Maciej A. Mazurowski, Duke Univ. (United States)

Purpose:

Digital breast tomosynthesis (DBT) has been shown to be superior to mammography as a screening tool for the detection of breast cancer: improved sensitivity, improved specificity, increased invasive cancer detection. As a result, DBT has the potential to replace mammography as the default breast cancer screening modality.

In order to incorporate DBT into routine practice, educators must train the next generation of radiologists how to properly utilize this new modality. However, the best means of introducing this new modality to radiology trainees with a diverse spectrum of prior breast imaging experience is not currently understood. Trainees with different levels of mammography as well as general radiology experience may perform very differently. The purpose of this study is to assess the effect of radiology experience on DBT performance among radiology trainees without prior DBT experience. The results might help guide the introduction of DBT training in radiology residency curriculum.

Materials and Methods:

Sixteen radiology residents without DBT experience reviewed 60 DBT studies, consisting of craniocaudal (CC) and medio-lateral oblique (MLO) views of a single breast. The DBT studies included a mix of normal, benign, and malignant abnormalities. The readers included first (n=2), second (n=2), third (n=3), and fourth (n=9) year radiology residents. Readers were asked to provide a final Breast Imaging-Reporting and Data System (BI-RADS) assessment. A breast imager with 7 years of experience performed the same task. Area under the ROC curve (AUC), sensitivity, and specificity were calculated to assess the performance of the residents. Assessments of the expert were used as the ground truth when calculating the resident AUCs. This approach was taken since it allows us to focus on resident error-making that is due to a lack of expertise (i.e., difference between them and the expert) rather than imperfections in the imaging modality (i.e., errors that any reader, regardless of experience level, might make). A two one-sided tests approach, with an AUC threshold value of 0.1, was used to test for equivalence between different groups of residents. This test compares two groups and a p value of less than 0.05 indicates that there is no difference between them, utilizing the threshold value to establish significance.

Results:

There were 22 worrisome abnormalities identified by the expert: 15 masses, 8 calcifications, and 2 asymmetries. We did not notice any strong relationship between the resident performance in DBT and the extent of their prior radiology training. The resident AUC was 0.700 ± 0.040 for first year residents, 0.626 ± 0.027 for second year residents, 0.667 ± 0.043 for third year residents, and 0.634 ± 0.062 for fourth year residents. A breakdown of trainee performance by year of training is shown in Figure 1. Performance was equivalent between second and fourth year residents (p=0.028) as well as between third and fourth year residents (p=0.048). The sensitivity was 0.795 (range: 0.773-0.818) for first year residents, 0.545 (range: 0.500-0.591) for second year residents, 0.606 (range: 0.318-0.773) for third year residents, and 0.697 (range: 0.591-0.818) for fourth year residents. The specificity was 0.566 (range: 0.473-0.658) for first year residents, 0.645 (range: 0.579-0.711) for second year residents, 0.667 (range: 0.553-0.868) for third year residents, and 0.553 (range: 0.211-0.737) for fourth year residents.

New or breakthrough work to be presented:

In this study we demonstrated that initial performance the newly introduced DBT is largely independent of years of training among radiology residents. Prior breast imaging experience does not appear to translate to improved performance with DBT. Educators should not assume that more senior radiology residents will initially perform better with DBT, and so teaching materials for trainees of all levels should be designed to appeal to a uniform basic level of understanding.

9416-3, Session 1

Detection of calcification clusters in digital breast tomosynthesis slices at different dose levels utilizing SRSAR reconstruction and JAFROC

Pontus A. Timberg, Scanias Univ. Hospital (Sweden) and Lund Univ. (Sweden); Magnus Dustler, Scanias Univ. Hospital (Sweden); Hannie Petersson, Scanias Univ. Hospital (Sweden); Anders Tingberg, Sophia Zackrisson, Scanias Univ. Hospital (Sweden)

Purpose: To investigate detection performance for calcification clusters in reconstructed digital breast tomosynthesis (DBT) slices at different dose levels using a Super Resolution and Statistical Artifact Reduction (SRSAR) reconstruction method developed by Siemens. Method: Simulated

calcifications with irregular profile (0.2 mm diameter) where combined to form clusters that were added to projection images (1-3 per abnormal image) acquired on a DBT system (Mammomat Inspiration, Siemens). The projection images were dose reduced by software to form 35 abnormal cases and 25 normal cases as if acquired at 100%, 75% and 50% dose level (AGD of approximately 1.6 mGy for standard breast, measured according to Euref v0.15). A SRSAR reconstruction method (utilizing IRIS (iterative reconstruction filters), and outlier detection using Maximum-Intensity Projections and Average-Intensity Projections) was used to reconstruct single central slices to be used in a Free-response task, (60 images per observer and dose level). Six medical physicists participated and their task was to detect the clusters and assign confidence rating in randomly presented images from the whole image set (balanced by dose level). Each trial was separated by two weeks to reduce possible memory bias. The outcome was analyzed for statistical differences in AFROC figure-of-merit using Jackknifed Alternative Free-response receiver operating characteristics (JAFROC). Results: The results indicate that it is possible reduce the dose by 25% without jeopardizing cluster detection. Conclusions: The detection performance for clusters can be maintained at a lower dose level by using SRSAR reconstruction.

9416-4, Session 2

Inter- and intra-observer variations in the delineation of sesions in mammograms

Thomas Buelow, Harald S. Heese, Ruediger Grewer, Dominik Kutra, Rafael Wiemker, Philips Research (Germany)

Many clinical and research tasks require the delineation of lesions in radiological images. There is a variety of methods available for deriving such delineations, ranging from free hand manual contouring, manual positioning of low-parameter graphical objects, to (semi-)automatic computerized segmentation methods. In this paper we investigate the impact of the chosen segmentation method on the inter-observer variability of the resulting contour. Three different methods are compared in this paper, namely (1) manual positioning of an ellipse, (2) an automatic segmentation method, coined live-segmentation, which depends on the current mouse pointer position as input information and is updated in real-time as the user hovers with the mouse over the image and (3) free form segmentation which is realized by allowing the user to pull the result of method (2) to image positions that the contour is required to pass. Each of the three methods was used by three experienced radiologists to delineate a set of 113 round breast lesions seen on digital mammograms. Agreement between contours was assessed by computing the Dice coefficient. The median Dice coefficient for the ellipses placed by different readers was 0.85. The intra-reader Dice coefficient comparing ellipses and live-segmentations was 0.86, thus showing that the live-segmentation results agree with ellipse segmentations to the same extent as readers agree on the ellipse placement. Inter-observer agreement when using the live-segmentation was higher than for the ellipses (median Dice = 0.93 vs. 0.85) showing that the live-segmentation is a more reproducible alternative to the ellipse placement.

9416-5, Session 2

Computational assessment of mammography accreditation phantom images and correlation with human observer analysis

Bruno Barufaldi, Univ. de São Paulo (Brazil) and Univ. of Pennsylvania (United States); Kristen C. Lau, Univ. of Pennsylvania (United States); Homero Schiabel, Univ. de São Paulo (Brazil); Andrew D. A. Maidment, Univ. of Pennsylvania (United States)

Screening for breast cancer requires careful quality control of images. The main purpose of this research is to develop a framework to monitor radiation dose and image quality in a mixed breast screening and diagnostic imaging environment using an automated tracking system. This study presents a module of this framework, consisting of a computerized system to measure the image quality of the American College of Radiology mammography accreditation phantom. The methods developed are a combination of correlation approaches, matched filters and data mining techniques. These methods have been used to analyze radiological images of the accreditation phantom. The classification of structures of interest is based upon reports produced by four trained readers. As previously reported, human observers demonstrate great variation in their analysis due to the subjectivity of human visual inspection. The software tool was trained with 30 phantom images. When tested with 120 images, the tool correctly classified 91.67%, 94.44%, and 91.33%, of fibers, speckle groups and masses, respectively. The variation between the computer classification and human reading was comparable to the variation between human readers. This computerized system not only automates the quality control procedure in mammography, but also decreases the subjectivity in the expert evaluation of the phantom images.

9416-6, Session 2

iDensity: an automatic Gabor filter-based algorithm for breast density assessment

Ziba Gamdonkar, William J. Ryder, Kevin Tay, Patrick C. Brennan, Claudia R. Mello-Thoms, The Univ. of Sydney (Australia)

Although many semi-automated and automated algorithms for breast density assessment have been recently proposed, none of these have been widely accepted. In this study a novel automated algorithm, named iDensity, inspired by the human visual system is proposed for classifying mammograms into four breast density categories corresponding to the Breast Imaging Reporting and Data System (BI-RADS). For each BI-RADS category 80 cases were taken from the normal volumes of the Digital Database for Screening Mammography (DDSM). For each case only the left medial-Lateral Oblique was utilized. After image calibration using the provided tables of each scanner in the DDSM, the pectoral muscle and background were removed. Images were filtered by a median filter and down sampled. Images were then filtered by a filter bank consisting of Gabor filters in six orientation and 3 scales, and a Gaussian filter. Three gray level histogram-based features and three second order statistics features were extracted from each filtered image. Using the extracted features, mammograms were separated in two groups, low or high density, at the first stage of classification. In the second stage, the low density group was subdivided into BI-RADS I or II, and the high density group into BI-RADS III or IV. The algorithm achieved a sensitivity of 95% and specificity of 94% in the first stage, sensitivity of 89% and specificity of 95% when classifying BI-RADS I and II cases, and a sensitivity of 88% and 91% specificity when classifying BI-RADS III and IV.

9416-7, Session 2

Assessment of mass detection performance in contrast enhanced digital mammography

Ann-Katherine Carton, GE Healthcare France (France); Zhijin Li, GE Healthcare France (France) and Ecole Normale Supérieure de Cachan (France); Clarisse Dromain, Institut Gustave Roussy (France); Serge L. Muller, GE Healthcare France (France)

In this work, we address the detectability of contrast uptakes in masses for contrast-agent enhanced spectral mammography (CESM), a dual-energy technique providing functional projection images of breast tissue

perfusion and vascularity. We first assess the realism of simulated CESM images from anthropomorphic breast software phantoms generated with a software X-ray imaging platform. We characterize breast texture by power-law coefficients calculated in data sets of real clinical and simulated CESM images. We also perform a two-alternative forced-choice (2-AFC) psychophysics experiment whereby regions of interest of real and simulated CESM images are shown side-by-side to experienced radiologists. It was found that texture in our simulated CESM images has a fairly realistic appearance. Then, we assess the relative performance of human readers versus previously developed mathematical observers for mass lesion detection in simulated CESM images. Detection performance is assessed for a range of contrast uptakes in masses. We design 4-AFC experiments using realistic mass lesions with variable shape. We investigate a number of linear multi-template models including the non-prewhitening matched filter observer with and without an eye filter and a channelized Hotelling observer. We hope that in the future, this framework of software breast phantoms, virtual image acquisition and processing, and mathematical observers can be beneficial to optimize CESM imaging techniques.

9416-8, Session 2

The relationship between socio-economic status and cancer detection at screening

Sian Taylor-Phillips, Toyin Ogboye, Tom Hamborg, The Univ. of Warwick (United Kingdom); Olive Kearins, Emma O'Sullivan, West Midlands Quality Assurance Reference Ctr., Public Health England (United Kingdom); Aileen Clarke, The Univ. of Warwick (United Kingdom)

It is well known that socio-economic status is a strong predictor of screening attendance, with women of higher socio-economic status more likely to attend breast cancer screening. We investigated whether socio-economic status was related to the detection of cancer at breast screening centres. In two separate projects we combined UK data from the population census, the screening information systems, and the cancer registry. Five years of data from all 81 screening centres in the UK was collected. Only women who had previously attended screening were included. The study was given ethical approval by the University of Warwick Biomedical Research Ethics committee reference SDR-232-07-2012. Generalised linear models with a log-normal link function were fitted to investigate the relationship between predictors and the age corrected cancer detection rate at each centre. We found that screening centres serving areas with lower average socio-economic status had lower cancer detection rates, even after correcting for the age distribution of the population (p<0.01). This may be because there may be a correlation between higher socio-economic status and some risk factors for breast cancer such as nullparity (never bearing children). However, analysis of full screening data sets at eight screening centre showed a positive correlation between lower socio-economic status and interval cancer detection (between screening rounds, p<0.01). We are in the process of analysing the relationship between socioeconomic status and screening characteristics (including mammographic appearance), and prognostic indicators after cancer detection.

9416-9, Session 2

The impact of mammographic imaging systems on density measurement

Christine N. Damases, Mark F. McEntee, The Univ. of Sydney (Australia)

The purpose of this study is to investigate whether having a mammogram on differing manufacturer equipment will effect a woman's breast density (BD) measurement. The data set comprised of 40 cases, each containing a combined image of the left craniocaudal (LCC) and left mediolateral oblique (LMLO). These images were obtained from 20 women age between 42–89 years. The images were acquired on two imaging systems (GE and Hologic)

one year apart. Volumetric BD was assessed by using Volpara Density Grade (VDG) and average BD% (AvBD%). Twenty American Board of Radiology (ABR) examiners assessed the same images using the BIRADS BD scale 1-4. Statistical comparisons were performed on the means using Mann-Whitney, on correlation using Spearman's rank coefficient of correlation and agreement using Cohen's Kappa. The mean BIRADS for GE was higher than Hologic (2.23 versus 2.07; p<0.043). The VDG measures for GE was not statistically different to Hologic (2.45 versus 2.50; p<0.485), likewise the mean AvBD% for the GE and Hologic systems showed no difference (9.64 versus 9.49; p<0.713). BIRADS for GE and Hologic systems showed strong positive correlation (?=0.904; p<0.001), while the VDG (?=0.978; p<0.001) and AvBD% (?=0.973; p<0.001) showed very strong positive correlations. There was a substantial agreement between GE and Hologic systems for BIRADS density shown with Cohen's Kappa (?=0.692; p<0.001), however the systems demonstrated an almost perfect agreement for VDG (?=0.933; p<0.001).

9416-10, Session 3

A phantom-based JAFROC observer study of two CT reconstruction methods: the search for optimisation of lesion detection and effective dose

John D. Thompson, Univ. of Salford (United Kingdom) and University Hospitals of Morecambe Bay NHS Foundation Trust (United Kingdom); Dev P. Chakraborty, Univ. of Pittsburgh (United States); Katy R. Szczepura, Univ. of Salford (United Kingdom); Ioannis Vamvakas, The Christie NHS Foundation Trust (United Kingdom); Andrew Tootell, Univ. of Salford (United Kingdom); David J. Manning, Lancaster Univ. (United Kingdom); Peter Hogg, Univ. of Salford (United Kingdom)

Purpose: To investigate the dose saving potential of adaptive iterative dose reconstruction 3D (AIDR3D) in a computed tomography (CT) examination of the thorax.

Materials and Methods: An anthropomorphic chest phantom containing various configurations of simulated lesions (5, 8, 10 and 12mm; +100, -630 and -800 Hounsfield Units, HU) was imaged on a modern CT system over a tube current range (20, 40, 60 and 80mA). Images were reconstructed with AIDR3D and filtered back projection (FBP). An ATOM 701D (CIRS, Norfolk, VA) dosimetry phantom was used to measure organ dose. Effective dose and effective risk were calculated. Eleven observers (15.11±8.75 years of experience) completed a free response study, localising lesions in 544 single CT image slices. A modified jackknife alternative free-response receiver operating characteristic (JAFROC) analysis was completed to look for a significant effect of two factors: reconstruction method and tube current. Alpha was set at 0.05 to control the Type I error in this study.

Results: For modified JAFROC analysis of reconstruction method there was no statistically significant difference in lesion detection performance between FBP and AIDR3D when figures-of-merit were averaged over tube current (F(1,10)=0.08, p = 0.789). For tube current analysis, significant differences were revealed between multiple pairs of tube current settings (F(3,10) = 16.96, p<0.001) when averaged over image reconstruction method.

Conclusion: The free-response study suggests that lesion detection can be optimised at 40mA in this phantom model, a measured effective dose of 0.97mSv. In high-contrast regions the diagnostic value of AIDR3D, compared to FBP, is less clear.

9416-11, Session 3

ROC curve estimation using two alternative binary classification

Francesc Massanes, Jovan G. Brankov, Illinois Institute of Technology (United States)

Image quality is typically quantified by the degree to which a human observer can perform a task, in a psychophysical human study, the observer is asked to input a numerical score, the observer's confidence in the image belonging to a class or not. Such scores are then used to measure receiver operating characteristic (ROC) curve and the observer performance. This type of human studies are time consuming, while two alternative forced choice (2AFC) studies are known to be shorter but cannot lead to a continuous set of scores and therefore cannot lead to the same performance metrics. In this paper we present a methodology to convert a series of 2AFC tasks into a continuous set of scores that can be used to more accurately estimate performance and ROC curves.

9416-12, Session 3

A multireader diagnostic performance study of low-contrast detectability on a third-generation dual-source CT scanner: filtered back projection versus advanced modeled iterative reconstruction

Justin B. Solomon, Achille Mileto, Duke Univ. School of Medicine (United States); Juan Carlos R. Giraldo, Siemens Medical Solutions USA, Inc. (United States); Ehsan Samei, Duke Univ. School of Medicine (United States)

The purpose of this work was to compare CT low-contrast detectability between two reconstruction algorithms, filtered back-projection (FBP) and advanced modeled iterative reconstruction (ADMIRE). A phantom was designed with a range of low-contrast circular inserts representing 5 contrast levels and 3 sizes. The phantom was imaged on a third-generation dual-source CT scanner (SOMATOM Definition Force, Siemens Healthcare) under various dose levels (0.74 – 5.8 mGy CTDIVol). Images were reconstructed using different settings of slice thickness (0.6 – 5 mm) and reconstruction algorithms (FBP and ADMIRE with strength of 3-5) and were assessed by eleven blinded and independent readers using a two alternative forced choice (2AFC) detection experiment. A second observer experiment was further performed in which observers scored the images based on the total number of visible insert groups. Detection performance increased with increasing contrast, size, dose, with accuracy ranging from 50% (i.e., guessing) to 87% with an average inter-observer variability of ±7%. The use of ADMIRE-3 increased performance by 5.2%. The insert counting experiment also showed increased number of visible insert groups (VIG) for increasing dose, slice thickness, and ADMIRE strength. The score difference between FBP and ADMIRE was 0.9 VIG, 1.3 VIG, and 2.1 VIG for ADMIRE strengths of 3, 4, and 5 respectively. Overall, the data indicated potential reduced dose with comparable image quality for ADMIRE.

9416-13, Session 3

Demonstration of multi- and single-reader sample size program for diagnostic studies software

Stephen L. Hillis, Kevin M. Schartz, The Univ. of Iowa (United States)

The recently released software Multi- and Single-Reader Sample Size Sample Size Program for Diagnostic Studies, written by Kevin Schartz and

Stephen Hillis, performs sample size computations for diagnostic reader-performance studies. The program computes the sample size needed to detect a specified difference in a reader performance measure, such as the AUC between two modalities when using the analysis methods initially proposed by Dorfman, Berbaum, and Metz (DBM) (1992) and Obuchowski and Rockette (OR) (1995), and later unified and improved by Hillis and colleagues (2005, 2007, 2008). The methodology that the program is based on for computing sample size and power is detailed in Hillis, Obuchowski, and Berbaum (2011).

The program can be used with typical reader-performance measures (e.g., ROC AUC), which can be estimated parametrically or nonparametrically. The program has an easy-to-use step-by-step intuitive interface that walks the user through the entry of the needed information. Features of the software include the following: (1) Choice of several study designs. (2) Choice of inputs obtained from either OR or DBM analyses. (3) Choice of three different inference situations: both readers and cases random, readers fixed and cases random, and readers random and cases fixed. (4) Choice of three types of hypotheses: nonequivalence, equivalence, or noninferiority. (6) Choice of two output formats: power for specified case and reader sample sizes, or a listing of case-reader combinations that provide a specified power. (7) Choice of single or multi-reader analyses. (8) Functionality in Windows, Mac OS, and Linux.

9416-14, Session 3

Low contrast detectability in CT for human and model observer in multi-slice data sets

Alexandre BA, Institut Univ de Radiophysique Appliquee (Switzerland); Damien Racine, Ctr. Hospitalier Univ. Vaudois (Switzerland); Julien G. Ott, Institut Univ. de Radiophysique Appliquée (Switzerland) and Lausanne Univ. Hopsital (Switzerland); Francis R. Verdun, Sabine Kobbe-Schmidt, Ctr. Hospitalier Univ. Vaudois (Switzerland); Miguel P. Eckstein, Univ. of California, Santa Barbara (United States); François O. Bochud, Ctr. Hospitalier Univ. Vaudois (Switzerland)

Task-based medical image quality is often assessed by model observers for single slice images but their performances have not been evaluated for clinical multi-slice (ms) images as input. The goal of the study was to determine if model observers can predict human detection performance of low contrast signals in CT for ms images. We collected 24 different data subsets from a low contrast phantom: 3 dose levels (40, 90, 150 mAs), 4 signals (6 and 8 mm diameter; 10 and 20 HU at 120kV) and 2 reconstruction algorithms (FBP and iterative (IR)). Images were assessed by human and model observers in 4-alternative forced choice (4AFC) experiment with ms data set in signal-known-exactly (SKE) paradigm. Model observers with single (msCHOa) and multiple (msCHOb) templates were implemented in a train and test method analysis with Dense Difference of Gaussian (DDoG) and Gabor spatial channels. For human observers, we found that percent correct increased with the dose and iterative reconstructed images exceed FBP in all investigated conditions. All model observers implemented overestimated human performance in any condition except one case (6mm and 10HU) for msCHOa and msCHOb with Gabor channels. Internal noise could be implemented and a good agreement was found but necessitates several independent fits according to the reconstruction method. Generally msCHOb shows higher detection performance than msCHOa with both types of channels. Gabor channels were less efficient than DDoG in this context. These results allow further developments in 3D analysis technique for low contrast CT.

9416-15, Session 4

Influence of the grayscale on phantom-based image quality assessment in x-ray computed tomography

Frédéric Noo, The Univ. of Utah (United States); Katharina Schmitt, Siemens Healthcare (Germany)

Radiation dose associated with CT scans has become an important concern in medical imaging. Fortunately, there are many pathways to reducing dose. A complicated aspect, however, is to ensure that image quality is not affected while reducing the dose. A preferred method to assess image quality is ROC analysis, possibly with a search process. For early assessment of new imaging solutions, utilization of human observers and real patient data is rarely practical. Instead, studies involving phantoms and model observers are often preferred. We present here an experimental result that sheds light on how the grayscale window affects human observer performance in a typical phantom-based study; and we also present an analysis that clarifies how the grayscale window affects the statistics of the image. These studies provide a better understanding of possible consequences associated with not including a grayscale window in studies with model observers, as is typical.

9416-16, Session 4

Combination of detection and estimation tasks using channelized scanning linear observer for CT imaging systems

Hsin-Wu Tseng, The Univ. of Arizona (United States); Jiahua Fan, Healthcare Systems, GE Healthcare (United States); Matthew A. Kupinski, The Univ. of Arizona (United States)

Maintaining or even improving image quality while lowering dose is always desirable in clinical CT imaging. Various image-reconstruction algorithms are available on current commercial CT systems, which are either provided by the manufacturers or generated by physicians and technologists. CT images are acquired so that specific medically relevant tasks can be performed. Thus, it is clear that image-quality assessment should be task-based and should involve a specific task, observer, and figure of merit. For example, channelized Hotelling observers (CHO) have been widely used for detection tasks. For estimation task, scanning linear observers (SLO) have been proven to be an effective tool. In this work, the outputs of channelized scanning linear observer (CSLO) is applied to study observer performance on a task that involves both detection and estimation. We compare task performance of CT image data acquired reconstructed using a conventional FBP reconstruction algorithm and a new developed iterative reconstruction (IR) algorithm. The purpose of this work is to design a robust approach of quantitative image-quality evaluation for CT systems. Low contrast objects imbedded in head size and body size phantoms are imaged multiple times to obtain better statistics. Independent signal present and absent image pairs are generated for CSLO trainings and testing. Estimation receiver operating characteristic (EROC) curves and the area under EROC curve (EAUC) are calculated using CSLO with Dense Difference of Gauss (DDOG) channels. The one-shot method is used to compute the variance of the EAUC values. Results suggest that equivalent image quality is achieved with a dose reduction of 54% if the new IR algorithm is used.

9416-17, Session 4

What observer models best reflect low-contrast detectability in CT?

Justin B. Solomon, Ehsan Samei, Duke Univ. School of Medicine (United States)

The purpose of this work was to compare CT low-contrast detectability as measured via human perception experiments with observer model surrogates of image quality, figures of merit (FOM), measured directly from the images. A phantom was designed with a range of low-contrast circular inserts representing 5 contrast levels and 3 sizes. The phantom was imaged repeatedly (20 times) on a third-generation dual-source CT scanner (SOMATOM Definition Force, Siemens Healthcare). Images were reconstructed at 0.6 mm slice thickness with filtered back projection (FBP) and advanced modeled iterative reconstruction and were assessed by eleven blinded and independent readers using a two alternative forced choice (2AFC) detection experiment. Several FOMs were measured directly from the images including contrast to noise ratio (CNR), Rose-model signal-to-noise ratio (SNRRose), non-prewhitening matched filter detectability index (d'NPW), and non-prewhitening matched filter with an eye filter detectability index (d'NPWE). These FOMs were transformed to a detection accuracy scale and correlated with human observer performance using linear regression analysis. The coefficient of determination (R^2) was used as goodness-of-fit metric to determine how well each FOM predicts human performance. R^2 was 0.12, 0.71, 0.73, and 0.77 for CNR, SNRRose, d'NPW, and d'NPWE respectively indicating superior representation of d'NPWE as a predictor of human performance. These data imply that objective FOMs could be used as surrogates of image quality for low-contrast detection tasks. These FOMs could help to optimize scan and reconstruction settings with the aim of minimizing dose and maximizing patient benefit.

9416-18, Session 4

CT image quality evaluation for detection of signals with unknown location, size, contrast and shape using unsupervised methods

Aria X. Pezeshk, Lucretiu M. Popescu, Berkman Sahiner, U.S. Food and Drug Administration (United States)

The advent of new image reconstruction and image processing techniques for CT images has increased the need for robust objective image quality assessment methods. One of the most common quality assessment methods is the measurement of signal detectability for a known signal at a known location using supervised classification techniques. However, this method requires a large number of simulations or physical measurements, and its underlying assumptions may be considered clinically unrealistic. In this study we focus on objective assessment of image quality in terms of detection of a signal with unknown location, size, shape, and contrast. We explore several unsupervised saliency detection methods which assume no knowledge about the signal, along with a template matching technique which uses information about the signal's size and shape in the object domain, for simulated phantoms that have been reconstructed using filtered back projection (FBP) and iterative reconstruction algorithms (IRA). The performance of each of the image reconstruction algorithms is then measured using the area under the localization receiver operating characteristic curve (LROC) and exponential transformation of the free response operating characteristic curve (EFROC). Our results indicate that unsupervised saliency detection methods can be effectively used to determine image quality in terms of signal detectability for unknown signals given only a small number of sample images.

9416-19, Session 4

Impact of number of repeated scans on model observer performance for a low-contrast detection task in CT

Chi Ma, Lifeng Yu, Baiyu Chen, Thomas J. Vrieze, Shuai Leng, Cynthia H. McCollough, Mayo Clinic (United States)

Channelized Hotelling observer (CHO) has been validated against human observers for detection/classification tasks in clinical CT and shows

encouraging correlations. However, the goodness of correlations depends on the number of repeated scans used in CHO to estimate the template and covariance matrices. The purpose of this study is to investigate how the number of repeated scans affects the CHO performance in predicting human observers. A phantom containing 21 low-contrast objects (3 contrast levels and 7 sizes) was scanned on a 128-slice CT scanner at three dose levels. Each scan was repeated 100 times. Images were reconstructed using a filtered-backprojection kernel and a commercial iterative reconstruction method. For each dose level and reconstruction setting, the low-contrast detectability, quantified with the area under receiver operating characteristic curve (Az), was calculated using a previously validated CHO. To determine the dependency of CHO performance on the number of repeated scans, the Az value was calculated for each object and dose/reconstruction setting using all 100 repeated scans. The Az values were also calculated using randomly selected subsets of the scans (from 10 to 90 scans with an increment of 10 scans). Using the Az from the 100 scans as the reference, the accuracy of Az from a smaller number of scans was determined. The minimum necessary number of scans was subsequently derived. For the studied signal-known-exactly detection task, results demonstrated that, the minimal number of scans required to accurately predict human observer performance depends on dose level, object size and contrast level, and channel filters.

9416-54, Session 4

Using the Wiener estimator to determine optimal imaging parameters in a synthetic-collimator SPECT system used for small animal imaging

Alexander L. Lin, Matthew A. Kupinski, College of Optical Sciences, The Univ. of Arizona (United States); Todd E. Peterson, Lindsay H. Johnson, Sepideh Shokouhi, Vanderbilt Univ. (United States)

In synthetic-collimator SPECT imaging, two detectors are placed at different distances behind a multi-pinhole aperture. This configuration allows for image detection at different magnifications and photon energies, resulting in higher overall sensitivity while maintaining high resolution. Image multiplexing – the undesired overlapping between images due to photon origin uncertainty – may occur in both detector planes and is often present in the second detector plane due to greater magnification. However, artifact-free image reconstruction is possible by combining data from both the front detector (little to no multiplexing) and the back detector (noticeable multiplexing). When the two detectors are used in tandem, spatial resolution is increased, allowing for a higher sensitivity to detector area ratio. Due to variability in detector distances and pinhole spacings found in synthetic-collimator SPECT systems, a large parameter space must be examined to determine optimal imaging configurations. We chose to assess image quality based on the task of estimating activity in various regions of a mouse brain. Phantom objects were simulated using mouse brain data from the Magnetic Resonance Microimaging Neurological Atlas (MRM NeAt) and projected through a simulated synthetic-collimator system at different angles. Uptake in the different brain regions was modeled as being normally distributed about predetermined mean values. We computed the performance of the Wiener estimator for the task of estimating activity in different regions of the mouse brain. Our results demonstrate the utility of the method for optimizing synthetic-collimator system design.

9416-21, Session 5

Extension of a model observer based on human perception to quantify the detectability of objects in dynamic noise

Georges Acharian, Trixell (France) and Gipsa-Lab (France); Nathalie Guyader, Gipsa-lab (France); Jean-Michel

Vignolle, Trixell (France); Christian Jutten, Gipsa-lab (France) and Institut Univ. de France (France)

In a previous paper, we proposed a model observer that mimics the sequence of eye fixations of an observer while exploring a noisy image to detect an object. Classical models (Hotelling, Non Prewhitening Matched Filter,...) compute a detectability index for an object in noise using the whole image. Instead, our proposed model, still based on decision theory, computes a detectability index locally on the salient areas of the object. This model was proved to return detectability indexes for various objects merged in static noise similar to the ones obtained for observers doing a detection task. In this paper, as X-ray detectors can provide sequences, we propose an extension of the previous model to detect objects in dynamic noise. Behavioral data are used to assess the efficiency of the model. During a psychophysical experiment, participants were asked to detect different objects in noisy sequences. Three different frame rates were tested. The luminance contrast of objects was adaptively adjusted according to the observer's response to obtain a percentage of correct detection of 50% for each object at a specific frame rate. The theoretical model uses properties of the visual system: when exploring a scene, we make several fixations at a rate of three to four fixations per seconds. Hence, the model still computes local detectability indexes on the salient areas of the object but rather than using one noise image, the noise power spectrum is decreased by averaging several noise images that appeared during the fixation. Results show that this extension is efficient to reproduce human results.

9416-22, Session 5

Active learning for model observer training data selection

Iris Lorente, Jovan G. Brankov, Illinois Institute of Technology (United States)

Model observers (MO) have been used in medical imaging as a surrogate of human observers to measure diagnostic accuracy, which is the finest criterion to assess medical image quality. These evaluations are important to optimize and test imaging reconstruction algorithms. The use of model observers to predict human diagnostic performance has been of great importance by reducing the number of human observer studies with expert readers, that are costly and time demanding.

Some types of MOs require a set of human scored images for tuning (training) the model. In this work, we present an active learning based approach to the problem of selecting a small set of images to be manually scored by humans and used to tune our MO while still providing accurate human predictions. Preliminary results indicate that the proposed data set selection approach, together with a learning model observer (LMO) based on the Relevance Vector Machine (RVM) has good performance in predicting human observer for diagnostic tasks.

9416-23, Session 5

Optimization of energy window and evaluation of scatter compensation methods in MPS using the ideal observer with model mismatch

Michael Ghaly, Jonathan M. Links, Eric C. Frey, Johns Hopkins Univ. (United States)

The Ideal Observer (IO) is a model observer that makes optimal use of all the information in the data. However, one limitation is that, since it has perfect knowledge of the image formation process, its performance reflects, in a sense, the best achievable with perfect compensation for all image-degrading factors. Thus using the IO to optimize imaging systems could lead to differences in optimal parameters compared to those optimized for humans interpreting SPECT images that are reconstructed with imperfect or no compensation. The IO with model mismatch (IO-MM) allows

incorporating imperfect system models into the IO optimization process.

In this work, we used the IO and IO-MM to optimize the Tc-99m acquisition energy window width and evaluate various scatter modeling and compensation methods, including the dual and triple energy window and effective source scatter estimation (ESSE) methods, in the context of a myocardial perfusion SPECT (MPS) binary (present or absent) defect detection task. The optimal energy window range when the IO-MM used an approximate model of scatter was narrower than that obtained using the IO, i.e., when the observer used a true scatter model. Results indicated that the ESSE scatter model was similar to using the true scatter model in terms of its effect on defect detection and optimal energy window. We also compared the performance of the IO and IO-MM with an anthropomorphic model observer, the Channelized Hotelling Observer (CHO). The IO-MM and CHO had the same performance rankings of the scatter estimation methods, with the ESSE method being the best, and equal (but poorer) performance achieved when using the dual and triple energy window methods. The agreement of rankings for the IO-MM and CHO suggests that the IO-MM may be useful for optimization tasks due to its substantially reduced computational burden compared to the CHO.

9416-24, Session 5

Approximate maximum likelihood estimation of scanning observer template

Craig K. Abbey, Univ. of California, Santa Barbara (United States); Frank W. Samuelson, Adam Wunderlich, Lucretiu M. Popescu, Subok Park, U.S. Food and Drug Administration (United States); John M. Boone, UC Davis Medical Ctr. (United States)

In localization tasks, an observer is asked to give the location of some target or feature of interest in an image. Scanning linear observer models incorporate the search implicit in this task through convolution of an observer template with the image being evaluated. Such models are becoming increasingly popular as predictors of human performance for validating medical imaging methodology. In addition to convolution, scanning models may utilize internal noise components to model inconsistencies in human observer responses. In this work, we build a probabilistic mathematical model of this process and show how it can, in principle, be used to obtain estimates of the observer template using maximum likelihood methods.

The main difficulty of this approach is that a closed form probability distribution for a maximal location response is not generally available in the presence of internal noise. However, for a given image we can generate an empirical distribution of maximal locations using Monte-Carlo sampling. We show that this probability is well approximated by applying an exponential function to the scanning template output.

We also have conducted psychophysical studies in forced localization tasks, where subjects indicate the location of a target in a search area of an image. The studies model the combination of power-law and ramp-spectrum noise that are the two main sources of variability in CT imaging. We compare the approximate ML estimates we obtain for this data to estimates made using simple averaging of noise fields.

9416-25, Session 5

The effect of signal variability on the histograms of anthropomorphic channel outputs: factors resulting in non-normally distributed data

Fatma Elzahraa A. Elshahaby, Michael Ghaly, Abhinav K. Jha, Eric C. Frey, Johns Hopkins Univ. (United States)

Model Observers are widely used in medical imaging for the optimization and evaluation of instrumentation, acquisition parameters and image

reconstruction and processing methods. The Channelized Hotelling observer (CHO) is a commonly used observer model in nuclear medicine with increasing uses in other modalities. The CHO consists of a set of channels that model some aspects of the human visual system, and is based on the Hotelling Observer, which is the optimal linear discriminant. The optimality of the CHO is based on the assumption that the channel outputs for data with and without the signal present have a multivariate normal distribution with equal class covariance matrices. The channel outputs result from the dot product of channel vectors with the image pixels and are thus the sum of a large number of random variables. The central limit theorem is thus often used to justify the assumption that the channel outputs are normally distributed. In this work, we aim to examine this assumption for realistically simulated medical images when various types of signal variability are present.

9416-26, Session 6

Effects of prevalence on visual search: a quantitative learning model and validation on human observer studies

Xin He, Frank W. Samuelson, Rongping Zeng, Berkman Sahiner, U.S. Food and Drug Administration (United States)

Signal prevalence powerfully influences many aspects of observer behavior. The goal of this work is to study the prevalence effects on visual search, which may allow researchers to predict or gain insight into real clinical performance in a low prevalence setting from data collected from high prevalence observer studies. Our study models how the observer learns signal prevalence from the data and how the perceived prevalence affects decision making. In the proposed model, the reader is treated as an equivalent ideal observer with a prior belief of the signal prevalence. For every new image, the reader updates his belief on prevalence and adjusts his decision threshold accordingly. The model is validated using an existing dataset from a recent large scale study conducted by Wolfe et al. to understand the effect of varying target prevalence on visual search. A total of 12 observers were recruited to perform 1000 trials of simulated baggage search as target prevalence varied sinusoidally from high to low and back to high. The results of the model on error rates agree well with the experimental results. This model allows theoretical insights into reader behavior in learning prevalence and adjusting decision threshold.

9416-27, Session 6

Ideal and visual-search observers: accounting for anatomical noise in search tasks with planar nuclear imaging

Anando Sen, Howard C. Gifford, Univ. of Houston (United States)

The ideal observer (IO) sets the upper bound for performance of a specific diagnostic task and is thus prescribed for optimizing image acquisitions. However, the relevance of IO optimizations for clinically realistic search tasks with human observers has not been investigated. We propose to compare collimator optimizations obtained with the IO, the prewhitening (PW) observer, the non-PW observer, the chanellized non-PW (CNPW) observer , visual-search (VS) observes and human observers for the task of lesion detection in planar nuclear imaging. A signal-known-statistically, background-known-statistically (SKS-BKS) task paradigm will be used for the IO and the various scanning observers. The VS observer accounts for anatomical noise without the BKS paradigm. Our initial work (described in this abstract) has tested the various model observers in a preliminary study with study images extracted from simulated prostate SPECT projection sets. Both detection and detection-localization tasks were considered, although the BKS paradigm was not implemented and no parameter optimization was carried out. Results of the collimator optimization study will be presented at the conference.

9416-28, Session 6

Priming cases disturb visual search patterns in screening mammography

Sarah J. Lewis, Warren M. Reed, Alvin N. Tan, Patrick C. Brennan, Warwick Lee, Claudia R. Mello-Thoms, The Univ. of Sydney (Australia)

Rationale and Objectives: To investigate the effect of inserting obvious cancers into a screening set of mammograms on the visual search patterns of radiologists. Previous research presents conflicting evidence as to the impact of priming in scenarios where prevalence is naturally low, such as in screening mammography.

Materials and Methods: An observer performance and eye position analysis study was performed. Four expert breast radiologists were asked to interpret two sets of 40 screening mammograms. The Control Set contained 36 normal and 4 malignant cases (located at case # 9, 14, 25 and 37). The Primed Set contained the same 34 normal and 4 malignant cases (in the same location) plus 2 "primer" malignant cases replacing 2 normal cases (located at positions #20 and 34). Primer cases were defined as lower difficulty cases containing salient malignant features inserted before cases of greater difficulty.

Results: Wilcoxon Signed Rank Test indicated no significant differences in sensitivity or specificity between the two sets (p > 0.05). The fixation count in the malignant cases (#25, 37) in the Primed Set after viewing the primer cases (#20, 34) decreased significantly (Z = -2.330, p = 0.020). Error type for False-Negatives were largely "sampling" in the Primed Set (75%) in contrast to in the Control Set (25%).

Conclusion: The performance of radiologists is not affected by the inclusion of obvious cancer cases. However, changes in visual search behavior, as measured by eye-position recording, suggest visual disturbance by salient inserted cases not normally seen in screening mammography.

9416-29, Session 6

Fractal analysis of radiologists' visual scanning pattern in screening mammography

Folami Alamudun, Texas A&M Univ. (United States); Hong-Jun Yoon, Oak Ridge National Lab. (United States); Kathleen Hudson, Garnetta Morin-Ducote, Univ. of Tennessee Medical Ctr. at Knoxville (United States); Georgia D. Tourassi, Oak Ridge National Lab. (United States)

Several investigators have investigated radiologists' visual scanning patterns with respect to features such as total time examining a case, time to initially hit true lesions, number of hits, etc. The purpose of this study was to examine the complexity of the radiologists' visual scanning pattern when viewing 4-view mammographic cases, as they typically do in clinical practice. Gaze data were collected from 10 readers (3 breast imaging experts and 7 radiology residents) while reviewing 100 screening mammograms (24 normal, 26 benign, 50 malignant). The radiologists' scanpaths across the 4 mammographic views were mapped to a single 2-D image plane. Then, fractal analysis was applied on the derived scanpaths using the box counting method. For each case, the complexity of each radiologist's scanpath was estimated using fractal dimension. The association between gaze complexity, case pathology, case density, and radiologist experience was evaluated using 3 factor fixed effects ANOVA. ANOVA showed that case pathology, breast density, and experience level are all independent predictors of the visual scanning pattern complexity. Visual scanning patterns are significantly different for benign and malignant cases than for normal cases as well as when breast parenchyma density changes.

9416-30, Session 6

Temporal stability of visual search-driven biometrics

Hong-Jun Yoon, Oak Ridge National Lab. (United States); Tandy R. Carmichael, Tennessee Technological Univ. (United States); Georgia D. Tourassi, Oak Ridge National Lab. (United States)

Previously, we have shown the potential of using an individual's visual search pattern as a possible biometric. That study focused on viewing images displaying dot-patterns with different spatial relationships to determine which pattern can be more effective in establishing the identity of an individual. In this follow-up study we investigated the temporal stability of this biometric. We performed an experiment with 16 individuals asked to search for a predetermined feature of a random-dot pattern as we tracked their eye movements. Each participant completed four testing sessions consisting of two dot patterns repeated twice. One dot pattern displayed concentric circles shifted to the left or right side of the screen overlaid with visual noise, and participants were asked which side the circles were centered on. The second dot-pattern displayed a number of circles (between 0 and 4) scattered on the screen overlaid with visual noise, and participants were asked how many circles they could identify. Each session contained 5 untracked tutorial questions and 50 tracked test questions (200 total tracked questions per participant). To create each participant's "fingerprint", we constructed a Hidden Markov Model (HMM) from the gaze data representing the underlying visual search and cognitive process. The accuracy of the derived HMM models was evaluated using cross-validation for various time-dependent train-test conditions. Subject identification accuracy ranged from 17.6% to 41.8% for all conditions, which is significantly higher than random guessing (1/16 = 6.25%). The results suggest that visual search pattern is a promising, fairly stable personalized fingerprint of perceptual organization.

9416-31, Session 6

Towards using eye tracking data to develop visual search for breast imaging

Zhihua Liang, Zhengqiang Jiang, Mini Das, Howard C. Gifford, Univ. of Houston (United States)

Visual-search (VS) model observers have the potential to provide reliable predictions of human-observer performance in detection-localization tasks. The purpose of this work is to examine characteristics of human gaze on breast images with the goal of informing the design of our VS observers. For this submission, we recording the movement of gaze and points of interest (POIs) from human observers as they searched for masses in a set of breast images. These POIs were then compared to the POIs obtained from a VS observer which identified "blob" clusters as suspicious locations. We are currently testing possible morphological features such as local gradient and contrast that can be used by the VS observer to explain the human results.

9416-32, Session 7

Improving lesion detectability in PET imaging with a penalized likelihood reconstruction algorithm

Kristen Wangerin, Univ. of Washington (United States) and General Electric Co. (United States); Sangtae Ahn, Steven G. Ross, General Electric Co. (United States); Paul E. Kinahan, Univ. of Washington (United States); Ravindra M. Manjeshwar, General Electric Co. (United States)

OSEM (ordered subset expectation maximization) is currently the most

widely used image reconstruction algorithm for clinical PET. However, OSEM does not necessarily provide optimal image quality, and a number of alternative algorithms have been explored. We have recently shown a PL (penalized likelihood) image reconstruction algorithm using the relative difference penalty achieves more accurate lesion quantitation than OSEM, and importantly, maintains acceptable visual image quality in clinical whole-body PET. Here the goal is to evaluate the lesion detectability of the PL algorithm, in comparison with OSEM, using a computer model observer. In this study we use 89 patient data sets and generate lesion-present data by simulating lesions in the liver and the lung. To measure lesion detectability, we apply a NPW (nonprewhitening) matched filter and CHO (channelized Hoteling observer) to OSEM and PL reconstructed images in the 2AFC (two-alternative forced choice) task and calculate the area under the ROC (receiver operating characteristic) curve. The PL algorithm yielded higher NPW and CHO AUC (area under the curve) values than OSEM in the lung. The results suggest the PL algorithm provides not only improved quantitation and clinically acceptable visual image quality as previously shown but also improved lesion detectability compared to OSEM.

9416-33, Session 7

SVM-based visual-search model observers for PET tumor detection

Anando Sen, Aixia Guo, Robert Azencott, Howard C. Gifford, Univ. of Houston (United States)

We have been investigating visual-search (VS) human-observer models. Our current two-phase VS observers perform an initial search to determine candidate locations based on morphological features and then analyze the candidates with a statistical discriminant. To extend the feature-based search, we have begun testing an SVM-based VS observer. This observer is applied to an image after an initial clustering has identified high-intensity blobs of interest. Sets of simulated 2D PET whole-body images were used to test the SVM observer, an existing VS observer and a scanning observer. Training of the SVM observer was accomplished using human-observer localization data as the "ground truth". In applying this observer, an initial set of 48 Leung-Malik features was extracted per image and recursive feature elimination (RFE) was then applied to assess the relative importance of the individual features. The effectiveness of the various model observers was measured in terms of concordance with human-observer localizations from tumor-present images. Overall, the SVM model performed better than the other models in this regard.

9416-34, Session 7

The use of kernel local Fisher discriminant analysis for the channelization of the Hotelling model observer

Gezheng Wen, Mia K. Markey, The Univ. of Texas at Austin (United States)

It is resource-intensive to conduct human studies for task-based assessment of medical image quality and system optimization. Thus, numerical model observers have been developed as a surrogate for human observers. The Hotelling observer (HO) is the optimal linear observer for signal-detection tasks, but the high dimensionality of imaging data results in a heavy computational burden. Channelization is often used to approximate the HO through a dimensionality reduction step, but how to produce channelized images without losing significant image information remains a key challenge. Kernel local Fisher discriminant analysis (KLFDA) uses kernel techniques to perform supervised dimensionality reduction, which finds an embedding transformation that maximizes between-class separability and preserves within-class local structure in the low-dimensional manifold. It is powerful for classification tasks, especially when the distribution of a class is multimodal. Such multimodality could be observed in many practical clinical tasks. For example, primary and metastatic lesions may both appear in medical imaging studies, but the distributions of their typical characteristics

(e.g., size) may be very different. In this study, we propose to use KLFDA as a novel channelization method. The dimension of the embedded manifold (i.e., the result of KLFDA) is a counterpart to the number of channels in the state-of-art linear channelization. We present a simulation study to demonstrate the practical usefulness of KLFDA for building the channelized HOs (CHOs) and generating reliable decision statistics for clinical tasks. We show that the performance of the CHO with KLFDA channels is comparable to that of the benchmark CHOs.

9416-35, Session 7

Evaluation of six channelized Hotelling observers in combination with a contrast sensitivity function to predict human observer performance

Marco Goffi, TweeSteden Ziekenhuis (Netherlands); Wouter J. H. Veldkamp, Leiden Univ. Medical Ctr. (Netherlands); Ruben E. van Engen, Ramona W. Bouwman, Dutch Reference Ctr. for Screening (Netherlands)

Standard methods to quantify image quality (contrast detail analysis and linear system theory) are not adequate for clinical images. Statistical model observers might be an alternative, since they are not dependent on uniform backgrounds and system linearity. One of these statistical model observers is the channelized Hotelling observer (CHO). The aim of this study was to evaluate six channel sets, with an additional filter to simulate the human contrast sensitivity function (CSF), in their ability to predict human observer performance. A two alternative forced choice (2-AFC) experiment was performed with 5 different object diameters, 3 different signal energies (SE) and two types of backgrounds (white noise (WN) and clustered lumpy background (CLB)). The results show that there is a good correlation between the human observers and the CHOs for the WN backgrounds. The sDoG and GC give the highest correlation (r2=0,64 and r2=0,60 respectively) with the human observer. However, this correlation is not present for CLBs, due to an apparent diameter dependency of the object. This dependency is subject of ongoing study.

9416-36, Session 7

On anthropomorphic decision making in a model observer

Ali R. N. Avanaki, Kathryn S. Espig, Albert Xthona, Barco, Inc. (United States); Tom R. L. Kimpe, Barco N.V. (Belgium); Predrag R. Bakic, Andrew D. A. Maidment, Univ. of Pennsylvania (United States)

By analyzing the performance of human readers in detecting small round lesions in simulated digital breast tomosynthesis background in a location known exactly scenario, we develop a model observer that is a better predictor of human performance in different levels of background complexity (i.e., anatomical and quantum noise). Our analysis indicates that the human observers seem to perform the detection task by combining a number of sub-decisions, each an indicator of presence of a lesion in the image stack. This is in contrast to a channelized Hotelling observer, where the detection task is conducted holistically by thresholding a single decision variable, made from an optimally weighted linear combination of channels. However, it seems that the subpar performance of the human readers compared to CHO cannot be fully explained by their reliance on sub-decisions, or perhaps we do not consider all sub-decisions that humans use. To bridge the gap between the performances of human readers and the model observer based upon sub-decisions, we use an additive noise model, the power of which is modulated with the level of background complexity. The proposed model observer better predicts the fast drop in human detection performance with background complexity that was reported in a prior study.

9416-37, Session 8

Comparison of two standalone computer-aided detection systems at multiple operating points

Berkman Sahiner, Weijie Chen, Aria X. Pezeshk, Nicholas A. Petrick, U.S. Food and Drug Administration (United States)

Computer-aided detection (CADe) systems are typically designed to work at a given operating point (OP): The device displays a mark if and only if the level of suspiciousness of a region of interest is above a fixed threshold. To compare the standalone performances of two systems, one approach is to select the parameters of the systems to yield a target false-positive rate that defines the OP, and to compare the sensitivities at that OP. Increasingly, CADe developers offer multiple OPs, which necessitates the comparison of two CADe systems involving multiple comparisons. To control the Type I error, multiple-comparison correction is needed for keeping the familywise error rate (FWER) less than a given alpha-level. The sensitivities of a single modality at different OPs are correlated. In addition, the sensitivities of the two modalities at the same or different operating points are also likely to be correlated. It has been shown in the literature that when test statistics are correlated, well-known methods for controlling the FWER are conservative. In this study, we compared the FWER and power of three methods, namely the Bonferroni, step-up, and adjusted step up methods in comparing the sensitivities of two CADe systems at multiple operating points, where the adjusted step-up method uses the estimated correlations. Our results indicate that the adjusted step-up method has a substantial advantage over other the two methods both in terms of the FWER and power.

9416-38, Session 8

Feasibility of using a biowatch to monitor GSR as a measure of radiologists' stress and fatigue

Elizabeth A. Krupinski, Lea MacKinnon, The Univ. of Arizona (United States); Bruce I. Reiner, Veterans Affairs Maryland Healthcare System (United States)

We have been investigating the impact of fatigue on diagnostic performance of radiologists interprteting medical images. In previous studies we found evidence that eye strain could be objectively measured and that it correlates highly with degradations in diagnostic accuracy as radiologists work long hours. Eye strain however can be difficult to measure in a non-invasive and continuous manner over the work day so we have been investigating other ways to measure physiological stress and fatigue. In this study we evaluated the feasibility of using a commercially available biowatch to measure galvanic skin response (GSR), a well known indicator of stress. 10 radiology residents wore the biowatch for about 8 hours during their normal work day and data were automatically collected at 10 Hz. They completed the Swedish Occupational Fatigue Inventory (SOFI) at the start and finish of the day. GSR values (microsiemens) ranged from 0.14 to 38.27 with an average of 0.50 (0.28 median). Overall GSR tended to be fairly constant as the day progressed, but there were definite spikes indicating higher levels of stress. SOFI scores indicated greater levels of fatigue and stress at the end of the work day. Although further work is needed, GSR measurements obtained via an easy to wear watch may provide a means to monitor stress/fatigue and alert radiologists when to take a break from interpreting images to avoid making errors.

9416-39, Session 8

Use of a computerized database of bone mineral density in order to improve the quality of diagnosis of osteoporosis in women

Igor Zakharov, Kemerovo State Medical Academy (Russian Federation)

Description of purpose. Osteoporosis is one of the leading non-communicable diseases worldwide. In women, the prevalence of osteoporosis was significantly higher than that of men. In the diagnosis of osteoporosis is important in bone mineral density (BMD) determination. One of the methods of investigation of bone mineral density is a dual-energy X-ray absorptiometry (DXA). During the DXA BMD absolute values are compared with a reference database that was originally put in the densitometric system. Most vehicles use a database, based on a study of the American population (NHANES III). Often the reference values of NHANES III does not correspond to the population-based indicators of other regions. The formation of osteoporotic changes affect different regional characteristics (geographic, ecological, ethnic, etc.). Kemerovo region has a high level of morbidity, including the skeletal system.

The aim of this work was the development of a computerized database of indicators of bone mineral density for women Kemerovo region.

Method. Based on the analysis results of 1504 dual-energy X-ray absorptiometry was formed population database mineral density of the lumbar vertebrae and proximal femur. The database shows the average bone mineral density in women of different age periods. Furthermore the mean values calculated standard deviation (SD), which allow to evaluate the Z-score. On the basis of this criterion is judged on the level of bone mineral density in women under 50 years of age. BMD data standardized for different densitometric systems (Lunar, Hologic, Norland).

Indicators of bone mineral density into the following age groups: 16-19 years, 20-29 years, 30-39 years, 40-49 years, 50-59 years, 60-69 years, 70-79 years, 80 years and older.

Results. Peak bone mass of the lumbar spine and proximal femur in women Kuzbass comes at the age of 20-29 years, then a decrease in BMD. Average peak bone mineral density in lumbar spine (L1-L4) in women Kemerovo region corresponds: for densitometric system Lunar 1,177 g/cm2, for a system Hologic - 1,043 g/cm2, for a system Norland - 1,051 g/cm2. Mean peak BMD of the proximal femur correspond to densitometric system Lunar 1,124 g/cm2, for a system of Hologic - 0,975 g/cm2 for the system Norland - 1,089 g/cm2. Developed database is intended to standardize the indicators of bone mineral density of women of the Kemerovo region, taking into account regional peculiarities.

"Input" is entered last name, first name, date of birth of the survey, and then - the type of densitometric system (Lunar, Hologic or Norland), which was scanned and the absolute values of bone mineral density of the lumbar vertebrae to the first through the fourth represents.

After that, the "output" indicators derived Z-criteria for each area of study. Conclusion is given in accordance with the recommendations of the WHO and the International Society for Clinical Densitometry.

New or breakthrough work to be presented. Using this program: allows for standardization and assessment of bone mineral density in women of the Kemerovo region, taking into account regional specificities; provides an assessment of bone mineral density for the different systems of the densitometer (Lunar, Hologic or Norland); allows information output to the printer.

Conclusions. Using the provided software improves the accuracy of the diagnosis of osteopenia and osteoporosis in women Kemerovo region.

9416-40, Session 8

Augmenting real-time video with virtual models for enhanced visualization for simulation, training and guidance

Alexander Bensch, Michael Potter, Alexander Dawson-Elli, Cristian A. Linte, Rochester Institute of Technology (United States)

In minimally invasive interventions, direct visualization of the surgical site is often not available, given the reduced size of the access route used to reach the organs to be treated. Instead, clinicians rely on different images from different sources, along with surgical navigation systems for guidance, using spatial localization and tracking systems, much-like the Global Positioning Systems (GPS) that we are all so familiar with. In this application we demonstrate how the video-feed from a camera, which could mimic a laparoscopic or endoscopic camera used during an interventional procedure, can be used to identify the pose of the camera with respect to the viewed scene and augment the video feed with computer-generated information, such as rendering of internal anatomy not visible beyond the image surface, resulting in a simple augmented reality environment. This paper describes the software and hardware environment and methodology for augmenting the real world with virtual models extracted from medical images to provide enhanced visualization beneath the surface view achieved using traditional surgical laparoscopes. Following intrinsic and extrinsic camera calibration, the technique was implemented and demonstrated using a LEGO-built phantom and a patient-specific left atrium mimicking phantom. We assessed the quality of the overlay according to the frame rate (frame rates over 25 Hz. being deemed acceptable), as well as the alignment error between the real and virtual views – which were in the range of the tracking accuracy featured by the camera, on the order of 3-5 mm. We will also explore stereoscopic visualization of the scene, as well as immersed virtual visualization using the Oculus Rift head-mounted display.

9416-41, Session 8

Objective evaluation of methods to track motion from clinical cardiac MRI sequences without the use of a gold standard

Felipe M. Parages, Illinois Institute of Technology (United States); Thomas S. Denney Jr., Auburn Univ. (United States); Jovan G. Brankov, Illinois Institute of Technology (United States)

Cardiac gated MRI is widely used for the task of measuring parameters related to heart motion. More specifically, gated tagged MRI is the preferred modality to estimate local deformation (strain) and rotational motion (twist) of myocardial tissue. Many methods have been proposed to estimate motion from gated MRI sequences. However, when dealing with clinical data, evaluation of these methods is problematic due to the absence of a gold-standard for cardiac motion. To overcome that, a linear regression scheme known as regression-without-truth (RWT) was proposed in the past. RWT uses priors to model the distribution of true values, thus enabling us to evaluate image modalities (or image-processing algorithms) without knowledge of the true data points. Furthermore, it allows one to rank different estimation methods by means of an objective figure-of-merit ?. In this work we apply RWT to compare the performance of several cardiac-MRI motion-tracking methods (e.g. non-rigid registration, feature based, harmonic phase) at the task of estimating myocardial strain and left-ventricle (LV) twist, from a population of 21 clinical human gated MRI studies.

9416-42, Session 8

Developing a clinical utility framework to evaluate prediction models in radiogenomics

Yirong Wu, Jie Liu, Alejandro Munoz del Rio, David C. Page, Oguzhan Alagoz, Univ. of Wisconsin-Madison (United States); Peggy Peissig, Adedayo A. Onitilo, Marshfield Clinic (United States); Elizabeth S. Burnside Rollins, Univ. of Wisconsin-Madison (United States)

Merging imaging and genetic information to predict disease presence and behavior is being codified into a new and exciting discipline called "radiogenomics." Optimal evaluation methodologies for radiogenomics techniques have not been established. We aim to develop a clinical decision framework based on utility analysis to assess radiogenomics prediction models for breast cancer. Our data comes from a retrospective case-control study, collecting Gail risk factors, genetic variants (single nucleotide polymorphisms-SNPs), and mammographic features in Breast Imaging-Reporting and Data System (BI-RADS) lexicon. We first constructed three logistic regression models built on different sets of predictive features: (1) Gail, (2) Gail+SNP, and (3) Gail+SNP+BI-RADS. Then, we generated ROC curves for three models. After we assigned utility values for each category of findings (true negative, false positive, false negative and true positive), we pursued optimal operating points on ROC curves to achieve maximum expected utility (MEU) of breast cancer diagnosis. We used McNemar's test to evaluate the predictive performance of three models. We found that SNPs and BI-RADS features augmented the baseline Gail model in terms of area under ROC curve (AUC) and MEU. SNPs improved sensitivity of the Gail model (0.276 vs. 0.147) but reduced specificity (0.855 vs. 0.912). When additional mammographic features were added, sensitivity increased to 0.457 and specificity to 0.872. SNPs and mammographic features played a significant role in breast cancer risk estimation (p-value < 0.001). Our decision framework comprising utility analysis and McNemar's test provides a novel framework to evaluate prediction models in the realm of radiogenomics.

9416-20, Session PSWed

Investigation on viewing direction dependent detectability in a reconstructed 3D volume for a cone beam CT system

Junhan Park, Changwoo Lee, Jongduk Baek, Yonsei Univ. (Korea, Republic of)

In medical imaging systems, several factors (e.g., reconstruction algorithm, noise structures, target size, contrast, etc) affect the detection performance and need to be considered for object detection. In a cone beam CT system, FDK reconstruction produces different noise structures in axial and coronal slices, and thus we analyzed directional dependent detectability of objects using detection SNR of channelized Hotelling observer. To calculate the detection SNR, difference-of-Gaussian channel model with 10 channels was implemented, and 20 sphere objects with different radius (i.e., 0.25 (mm) to 5 (mm) equally spaced by 0.25 (mm)), reconstructed by FDK algorithm, were used as object templates. Covariance matrix in axial and coronal direction was estimated from 3000 reconstructed noise volumes, and then the SNR ratio between axial and coronal direction was calculated. Corresponding 2D noise power spectrum was also calculated. The results show that as the object size increases, the SNR ratio decreases, especially lower than 1 when the object size is larger than 2.5 mm radius. The reason is because the axial (coronal) noise power is higher in high (low) frequency band, and therefore the detectability of a small (large) object is higher in coronal (axial) images. Our results indicate that it is more beneficial to use coronal slices in order to improve the detectability of a small object in a cone beam CT system.

9416-43, Session PSWed

Evaluation of a simulation procedure designed to recognize shape and contour of suspicious masses in mammography

Maria Angelica Z. Sousa, Paula N. Siqueira, Homero Schiabel, Univ. de São Paulo (Brazil)

A large number of breast phantoms have been developed for conducting quality tests, characterization of imaging systems and computer aided diagnosis schemes, dosimetry and image perception. The realism of these phantoms is important for ensuring the accuracy of results and a greater range of applications. In this work, a developed phantom is considered proposing the use of PVC films for simulation of nodules inserted in the breast parenchyma designed for classification between malignant and benign signals according to the BI-RADS® standard. The investigation includes analysis of radiographic density, mass shape and its corresponding contour outlined by experienced radiologists. The material was cut based on lesions margins found in 44 clinical cases, which were divided between circumscribed and spiculated structures. Tests were performed to check the ability of the specialist in distinguishing the contour compared to actual cases while the shapes accuracy was determined quantitatively by evaluation metrics. Results showed the applicability of the chosen material creating image radiological patterns very similar to the actual ones.

9416-44, Session PSWed

Objective evaluation of reconstruction methods for quantitative SPECT imaging in the absence of ground truth

Abhinav K. Jha, Johns Hopkins Univ. (United States); Na Song, Albert Einstein College of Medicine (United States); Eric C. Frey, Johns Hopkins Univ. (United States)

Quantitative single-photon emission computed tomography (QSPECT) imaging is emerging as an important tool in clinical studies and biomedical research. There is a need for evaluation and optimization of systems and algorithms that are being developed for QSPECT imaging. An appropriate objective method to evaluate these systems is by comparing their performance in the end task that is required in QSPECT imaging, such as estimating the mean activity concentration in a volume of interest (VOI) in a patient image. This objective evaluation can be performed if the true value of the estimated parameter is known, i.e. we have a gold standard. However, very rarely is the gold standard known in human studies. Thus, there is a need for no-gold-standard techniques for QSPECT imaging. In this work, we developed a technique for objectively evaluating reconstruction methods used in QPSECT imaging in the absence of a ground truth when the parameter to be estimated is the mean activity concentration in a VOI. We validated the technique with realistic simulated image data generated from an object database consisting of five phantom anatomies with all possible combinations of five sets of organ uptakes, where each anatomy consisted of eight different organ VOIs. Results indicate that the method provided accurate and reliable ranking of the reconstruction methods for multiple noise realizations. We also demonstrated the application of consistency checks to test the no-gold-standard output. The method can be applied to quantitative evaluation of activity concentration estimation using patient data and extended to objectively evaluate QSPECT imaging systems and algorithms for other quantitative tasks such as VOI segmentation, registration, and estimation of other quantitative parameters.

9416-45, Session PSWed

Comparing prediction models for radiographic exposures

William Ching, The Univ. of Sydney (Australia) and Brain &
Mind Research Institute (Australia); Mark F. McEntee, Brain & Mind Research Institute (Australia); John W. Robinson, The Univ. of Sydney (Australia)

During radiographic exposures the milliampere-seconds (mAs) and kilovoltage peak (kVp) must be adjusted for patient thicknesses. Several exposure adjustment systems have been developed to assist with this selection. This study compares the accuracy of four systems to predict the required mAs for pelvic radiographs taken on a direct digital radiography system (DDR).

Sixty radiographs were obtained using varying combinations of source-to-image distance (SID), kVp and patient thicknesses. The 25% rule, the DuPont™ Bit System and the DigiBit system were compared to determine which of these three most accurately predicted the mAs required for an increase in patient thickness. Similarly, the 15% rule, the DuPont™ Bit System and the DigiBit system were compared for an increase in kVp. The exposure index (EI) was used as an indication of exposure to the DDR. For each exposure combination the mAs was adjusted until an EI of 1500+/-2% was achieved.

The 25% rule was the most accurate at predicting the mAs required for an increase in patient thickness, with 53% of the mAs predictions correct. The DigiBit system was the most accurate at predicting mAs needed for changes in kVp, with 33% of predictions correct.

This study demonstrated that the 25% rule and DigiBit system were the most accurate predictors of mAs required for an increase in patient thickness and kVp respectively. The DigiBit system worked well in both scenarios as it is a single exposure adjustment system that considers a variety of exposure factors.

9416-46, Session PSWed

Experience in reading digital images may decrease observer accuracy in mammography

Mohammad A. Rawashdeh, Sarah J. Lewis, The Univ. of Sydney (Australia); Warwick Lee, The University of Sydney (Australia); Claudia R. Mello-Thoms, Warren M. Reed, Mark F. McEntee, The Univ. of Sydney (Australia); Kriscia Tapia, The University of Sydney (Australia) and Univ of Sydney (Australia); Patrick C. Brennan, The Univ. of Sydney (Australia)

This study aims to identify which parameters are linked to higher levels of performance in screening mammography. In particular we explored amongst other factors whether previous experience in digital images reading enhances radiologists performance when reporting on a digital cases. A total of 60 cases were presented, of which 20 contained cancer and 40 of which showed no abnormality. Each case comprised of four images and were shown to 129 breast readers. All readers were employed in breast reading activities as part of their clinical duties. Each individual reader was asked to identify and locate any visualized malignancies and provide a confidence rating using a scale of 1-5. All images were displayed using 5MP monitors, supported by radiology workstations with full image manipulation capabilities and a jack-knife free-response receiver operating characteristic, figure of merit (JAFROC, FOM) methodology was employed to assess reader performance. Details were obtained from each reader regarding their experience, qualifications and breast reading activities. Spearman and Mann Whitney techniques were used for statistical analysis. Higher performance was positively related to numbers of years professionally qualified (r= 0.18; P=0.04), number of years reading breast images (r= 0.24; P=0.007), number of mammography images read per week (r= 0.31; P=0.0003) and number of hours reading mammographic images per week (r= 0.2; P=0.02). Unexpectedly, higher performance was inversely linked to previous experience with d images (r= - 0.17; p=0.05) and further analysis, demonstrated that this finding was due to changes in specificity. The suggestion that readers with experience in digital images reporting may exhibit a reduced ability to correctly identify normal appearances requires further investigation.

9416-47, Session PSWed

The effect of NPS calculation method on power-law coefficient estimation accuracy in breast texture modeling

Zhijin Li, GE Healthcare France (France) and Ecole Normale Supérieure de Cachan (France); Ann-Katherine Carton, Serge L. Muller, R?zvan Lordache, GE Healthcare France (France); Agnès Desolneux, Ecole Normale Supérieure de Cachan (France)

In breast x-ray imaging, breast texture has been characterized by a noise power spectrum (NPS) that has an inverse power-law shape with exponent β. Estimation of the power-law coefficient β is a multiple step procedure and for each step several alternative algorithms have been proposed. Each of them can lead to biases of the estimated β. We investigated the effect of commonly used algorithm steps on the bias of β. First, the effect of the region of interest (ROI) size and percentage of overlap in the ROIs used to compute the 2D NPS were investigated. Second, we investigated the effect of a window function typically applied to reduce spectral leakage. Third, we analyzed alternative ways of radial frequencies determination in assessing radial NPS from 2D NPS. The effects of these three factors were analytically derived and validated using synthetic images with known β. β was varied from one to four to cover the range of textures encountered in 2D and 3D breast x-ray imaging. A non-negligible bias, strongly dependent on β, occurs when using overlapping ROIs and a window function. The methods tested to assess the radial NPS give rise to small biases in β. While many subtleties in real images were not modeled to simplify the mathematics in deriving our results, this work is illustrative in demonstrating the limits of commonly used algorithm steps to estimate accurate β values.

9416-48, Session PSWed

The role of digital tomosynthesis in reducing the number of equivocal breast reportings

Maram M. Alakhras, The Univ. of Sydney (Australia); Claudia R. Mello-Thoms, The Univ. of Sydney (Australia) and Univ. of Pittsburgh (United States); Mary Rickard, Roger Bourne, Patrick C. Brennan, The Univ. of Sydney (Australia)

Purpose:

To compare radiologists' confidence in assessing breast cancer using digital mammography (DM) and digital breast tomosynthesis (DBT) together with that of DM alone as a function of radiologists' previous experience with DBT.

Materials and Methods:

Human ethics approval was obtained. Twenty-six experienced radiologists reviewed 50 cases in two modes, DM alone and DM+DBT. Each radiologist was asked to detect breast lesions and give a confidence score of 1-5 (1- Normal, 2- Benign, 3- Equivocal, 4- Suspicious, 5- Malignant). Radiologists were divided into three sub-groups according to their experience with DBT (none, workshop experience, and clinical experience). The radiologists' confidence scores with DM+DBT were compared with that using DM alone for all readers combined and for each subgroup. Statistical analyses, using GraphPad Prism 5, were carried out using the Wilcoxon signed-rank test with statistical significance set at p< 0.05.

Results:

Confidence scores were significantly higher for cancer cases using DM+DBT compared with DM for all readers (p< 0.001), and for each of the subgroups: readers with no DBT experience (p= 0.003); readers with DBT workshop (p< 0.001); and readers with clinical DBT experience (p< 0.001). Confidence scores for normal/benign cases were significantly lower (indicating greater confidence in the non-cancer diagnosis) with DM+DBT compared with DM

for all readers (p< 0.001), the subgroup with no DBT experience (p< 0.001), and the subgroup with workshop experience (p< 0.001).

Conclusion:

Addition of DBT to DM increases the confidence level of radiologists in scoring cancer and normal/benign cases regardless of previous experience with DBT.

9416-49, Session PSWed

Image-domain sampling properties of the Hotelling observer in CT using filtered back-projection

Adrian A. Sanchez, Emil Y. Sidky, Xiaochuan Pan, The Univ. of Chicago Medical Ctr. (United States)

The Hotelling Observer (HO), along with its channelized variants, has been proposed for image quality evaluation in x-ray CT. In this work, we investigate HO performance for a detection task in parallel-beam FBP as a function of two image-domain sampling parameters, namely pixel size and field-of-view. These two parameters are of central importance in adapting HO methods to use in CT, since the large number of pixels in a single image makes direct computation of HO performance for a full image infeasible in most cases. Reduction of the number of image pixels and/or restriction of the image to a region-of-interest (ROI) has the potential to make direct computation of HO statistics feasible in CT, provided that the signal and noise properties lead to redundant information in some regions of the image. For small signals, we hypothesize that reduction of image pixel size and enlargement of the image field-of-view are approximately equivalent means of gaining additional information relevant to a detection task. The rationale for this hypothesis is that the back-projection operation in FBP introduces long-range correlations so that, for small signals, the reconstructed signal outside of a small ROI is not linearly independent of the signal within the ROI. In this work, we perform a preliminary investigation of this hypothesis by sweeping these two sampling parameters and computing HO performance for a signal detection task.

9416-50, Session PSWed

Evaluation of angiogram visualization methods for fast and reliable aneurysm diagnosis

Žiga Lesar, Ciril Bohak, Matija Marolt, Univ. of Ljubljana (Slovenia)

In this paper we present the results of an evaluation of different visualization methods for angiogram volumetric data - ray casting, marching cubes, and multi-level partition of unity implicits. There are several options available with ray-casting: isosurface extraction, maximum intensity projection and alpha compositing, each producing fundamentally different results. Different visualization methods are suitable for different needs, so this choice is crucial in diagnosis and decision making processes. We also evaluate visual effects such as ambient occlusion, screen space ambient occlusion, and depth of field. Some visualization methods include transparency, so we address the question of relevancy of this additional visual information. We employ transfer functions to map data values to color and transparency, allowing us to view or hide particular tissues. All the methods presented in this paper were developed using OpenCL, striving for real-time rendering and quality interaction. A small-scale evaluation has been conducted, showing that visual effect may positively or negatively affect perception of depth, motion, and relative positions in space.

9416-51, Session PSWed

Sparsity-driven ideal observer for computed medical imaging systems

Kun Wang, Yang Lou, Washington Univ. in St. Louis (United States); Matthew A. Kupinski, College of Optical Sciences, The Univ. of Arizona (United States); Mark A. Anastasio, Washington Univ. in St. Louis (United States)

The Bayesian ideal observer (IO) has been widely advocated to guide hardware optimization. However, except for special cases, computation of the IO test statistic is computationally burdensome and requires an appropriate stochastic object model that may be difficult to determine in practice. Modern reconstruction methods, referred to as sparse reconstruction methods, exploit the fact that objects of interest typically possess sparse representations and have proven to be highly effective at reconstructing images from under-sampled measurement data. Moreover, in computed imaging approaches that employ compressive sensing concepts, imaging hardware and image reconstruction are innately coupled technologies. In this work, we formulate sparsity-driven IOs (SD-IOs) to guide hardware optimization of modern computed imaging systems. The SD-IOs assume knowledge of low-level statistical properties of the object that are related to sparsity, and will therefore exploit the same statistical information regarding the object that is utilized by highly effective sparse image reconstruction methods. To efficiently compute SD-IO performance, we will estimate the posterior distribution by use of computational tools developed recently for variational Bayesian inference with sparse linear models. By use of the estimated posterior distribution, the SD-IO test statistic will be computed analytically.

9416-52, Session PSWed

Characterization of breast density in women from Lima, Peru

Fanny L. Casado, Pontificia Univ. Católica del Perú (Peru); Susan Leslie Manrique Solorzano, Pontificia Univ. Catolica del Peru (Peru); Jorge Guerrero, Joseph A. Pinto, Oncosalud (Peru); Jose Ferrer, Medical Innovation and Technology (Peru); Benjamin Castañeda, Pontificia Univ. Católica del Perú (Peru)

Data from GLOBOCAN show that around 4,000 Peruvian women are diagnosed with breast cancer every year. From these new cases, the clinical presentation of 36% corresponded to advanced stages (III and IV). Therefore, there is an urgent need to strengthen current screening and early detection strategies. Epidemiological evidence suggests that the Peruvian population may have a different stratification of risk based on its particular genetic and/or ethnic background. The present work aims to describe breast density using ACR breast density categories in a population of women from the city of Lima, Peru to aid in the development of novel strategies for screening and early detection of breast malignancies. We created a database by randomly selecting 1,100 non-pathologic mammographic images from two sources: an oncological clinic and a mobile mammography unit in order to include a diverse population. According to a team of radiologists, most of the mammograms in our database were assigned ACR-2. In contrast, at the time of acquisition most of the mammograms were assigned ACR-1. Also, no correlations were found in the distribution of ACR when compared to age or parity. The variability between the distributions of ACR might be attributed to different factors including the experience of the observer obtained during training and clinical practice with the diverse population present in Lima. The LIM database of mammograms can be used as a diverse well annotated instrument to train radiologists and develop better strategies to stratify breast cancer risk in women of Lima, Peru.

9416-53, Session PSWed

Evaluating RVUs as a measure of workload for use in assessing fatigue

Elizabeth A. Krupinski, The Univ. of Arizona (United States); Lea MacKinnon, Karl Hasselbach, University of Arizona (United States); Mihra Taljanovic, The Univ. of Arizona (United States)

Practices use RVUs for compensation, reflecting time required and case complexity but do not measure individual workload. Physician work however is not well defined and does not take into account all of the activities and tasks involved in interpreting cases. We observed 3 MSK radiologists reading 100 cases recording case type, whether residents/fellows were present, time per case, time spent teaching, and interruptions. 68% of the cases were radiographs, 19% MRI, 11% CT, and 2% US and 25% of the cases had priors that were accessed for comparison purposes. Overall, priors were accessed for 25% of the cases, with radiographs and CT accessing them more than MRI and US. Time per case was significantly longer when priors were included than when they were not. On average, when residents/fellows were present it took significantly longer to read cases. Time per case was significantly longer when priors were included. The radiologists were observed for 813.30 minutes of which 75.15 were taken up by distractions/interruptions. It is important to note that all of the interruptions occurred during a case review – meaning the radiologist was reviewing a case, got interrupted, then had to return to the case (as Figure 3 shows, often minutes later) and either start all over or try to remember where they were in the interpretation process. RVU data correlated 0.215 with time/case. RVUs are not an accurate reflection of the time and effort radiologists devote to case interpretation.

9416-55, Session PSWed

Implementation and value of using a split-plot reader design in a study of digital breast tomosynthesis in a breast cancer assessment clinic

Suneeta Mall, Patrick C. Brennan, Claudia R. Mello-Thoms, The Univ. of Sydney (Australia)

Digital Breast Tomosynthesis (DBT) seeks to reduce some of the shortcomings of Digital Mammography (DM), such as false recalls due to tissue overlap. Studies have evaluated the use of DBT in breast cancer screening with promising results, indicating that the use of DBT may improve cancer detection, lesion visibility and reduce recall rates. We aim to evaluate the efficacy of DBT in cancer assessment at our institute and to determine whether improved lesion visibility in DBT assists in cancer identification on multi-level (benign, normal and malignant) truth. To size this trial, we evaluated both a traditional fully crossed multi-reader-multi-case (MRMC) design and also a "split-plot" MRMC design. We aimed to optimize on the requisite costs associated with time and resources without adversely affecting the variance of the study. According to our calculations, which were based on a traditional fully crossed study with 26 readers and 50 cases (27 malignant), the variance obtained in a fully crossed design using 9 readers and 1000 cases (100 cancers) is comparable to that obtained when using a split-plot design with as many readers (in 3 non-overlapping blocks) and 216 cases/reader. Hence, use of the split-plot design not only reduces number of cases per reader but also reduces total interpretations by more than three times.

9416-57, Session PSWed

Investigation of methods for calibration of classifier scores to probability of disease

Weijie Chen, Berkman Sahiner, Frank W. Samuelson, Aria X. Pezeshk, Nicholas A. Petrick, U.S. Food and Drug Administration (United States)

Classifier output scores in many diagnostic devices, such as computer-aided diagnosis systems, are usually on an arbitrary scale, the meaning of which is unclear. Calibration of classifier scores to a meaningful scale such as the probability of disease is potentially useful when such scores are used by a physician or another algorithm. In this work, we investigated the properties of two methods for calibrating classifier scores to probability of disease. The first is a semi-parametric method in which the likelihood ratio for each score is estimated based on a semi-parametric proper receiver operating characteristic model, and then an estimate of the probability of disease is obtained using the Bayes theorem. The second method is non-parametric in which isotonic regression via the pool-adjacent-violators algorithm is used. Using simulated data for which the true probability of disease can be computed analytically, we employ the root mean square error (RMSE) to evaluate the two methods. We evaluate the methods under two paradigms: (a) the dataset used to construct the score-to-probability mapping function is used to calculate the RMSE (resubstitution); (b) an independent dataset is used to calculate the RMSE (independent). Our preliminary results indicate that the semi-parametric method performs better than the non-parametric method in terms of RMSE for a variety of sample sizes. Surprisingly, our results indicate that the resubstitution RMSE is almost identical to the RMSE calculated on independent datasets for both methods, implying overfitting appears unlikely for these data set sizes.

Conference 9417: Biomedical Applications in Molecular, Structural, and Functional Imaging

Tuesday - Thursday 24–26 February 2015

Part of Proceedings of SPIE Vol. 9417 Medical Imaging 2015: Biomedical Applications in Molecular, Structural, and Functional Imaging

9417-1, Session 1

Developing hyperpolarized silicon particles for advanced biomedical imaging applications

Nicholas Whiting, The Univ. of Texas M.D. Anderson Cancer Ctr. (United States); Jingzhe Hu, The Univ. of Texas M.D. Anderson Cancer Ctr. (United States) and Rice Univ. (United States); Pamela Canstaninou, Rice Univ. (United States); Niki Z. Millward, James A. Bankson, The Univ. of Texas M.D. Anderson Cancer Ctr. (United States); David Gorenstein, The Univ. of Texas Health Science Ctr. at Houston (United States); Anil Sood, The Univ. of Texas M.D. Anderson Cancer Ctr. (United States); Daniel Carson, Rice Univ. (United States); Pratip K. Bhattacharya, The Univ. of Texas M.D. Anderson Cancer Ctr. (United States)

Silicon-based nanoparticles are ideally suited as biomedical imaging agents, due to their biocompatibility, biodegradability, and simple surface chemistry that is amenable to drug loading and targeting. We have recently developed a method of hyperpolarizing silicon particles using dynamic nuclear polarization (DNP), which increases magnetic resonance imaging (MRI) signals by 4-5 orders of magnitude through enhanced nuclear spin alignment. Naturally occurring electronic defects on the particle surface obviate the need for exogenous radicals, and the enhanced spin polarization lasts for significantly longer than other hyperpolarized agents (tens of minutes, instead of <1 minute for other hyperpolarized species). We report our recent advances in determining the MR characteristics of hyperpolarized silicon particles, which could lead to non-invasive, non-radioactive molecular targeted imaging of various cancer systems. A variety of particle sizes (20 nm-2 um) were found to have hyperpolarized relaxation times ranging from ~10-50 minutes. The addition of various functional groups to the particle surface, including polyethylene glycol and an E-selectin thioaptamer (for targeting ovarian cancer) had no effect to the hyperpolarization dynamics or relaxation times, which appear to be a function of the particle size and purity. Anti-MUC1 antibodies (for targeting colorectal cancer) attached to the particle surface satisfactorily survived the harsh temperature conditions of DNP. Preliminary in vivo studies examined a variety of particle administration routes in mice, including intraperitoneal, tail vein, and rectal injections, as well as oral gavage. Ongoing experiments include targeted molecular imaging in orthotopic murine models of ovarian and colorectal cancers.

9417-2, Session 1

Development of a diaphragmatic motion-based elastography framework for assessment of liver stiffness

Jared A. Weis, Allison M. Johnsen, Geoffrey E. Wile, Thomas E. Yankeelov, Richard G. Abramson, Michael I. Miga, Vanderbilt Univ. (United States)

Evaluation of mechanical stiffness imaging biomarkers, through magnetic resonance elastography (MRE), has shown considerable promise for non-invasive assessment of liver stiffness to monitor hepatic fibrosis. MRE typically requires specialized externally-applied vibratory excitation and scanner-specific motion-sensitive pulse sequences. In this work, we have developed an elasticity imaging approach that utilizes natural diaphragmatic respiratory motion to induce deformation and eliminates the need for external deformation excitation hardware and specialized pulse sequences. Our approach uses clinically-available standard of care volumetric imaging acquisitions, combined with offline model-based post-processing to generate volumetric estimates of stiffness within the liver and surrounding tissue structures. We have previously developed a novel methodology for non-invasive elasticity imaging which utilizes a model-based elasticity reconstruction algorithm and MR image volumes acquired under different states of deformation. In prior work, deformation was external applied through inflation of an air bladder placed within the MR radiofrequency coil. In this work, we extend the methodology with the goal of determining the feasibility of assessing liver mechanical stiffness using diaphragmatic respiratory motion between end-inspiration and end-expiration breath-holds as a source of deformation. We present initial investigations towards applying this methodology to assess liver stiffness in healthy volunteers and cirrhotic patients. Our preliminary results suggest that this method is capable of non-invasive image-based assessment of liver stiffness using natural diaphragmatic respiratory motion and provides considerable enthusiasm for extension of our approach towards monitoring liver stiffness in cirrhotic patients with limited impact to standard-of-care clinical imaging acquisition workflow.

9417-3, Session 1

Repeatability assessment of modality independent elastography in a pre-clinical murine model

Katelyn M. Flint, Jared A. Weis, Thomas E. Yankeelov, Michael I. Miga, Vanderbilt Univ. (United States)

Changes in tissue mechanical properties, measured non-invasively by elastography methods, have been shown to be an important diagnostic tool, particularly for cancer. Tissue elasticity information, tracked over the course of therapy, may be an important prognostic indicator of tumor response to treatment. While many elastography techniques exist, this work reports on the use of a novel form of elastography that uses image texture to reconstruct elastic property distributions in tissue (i.e., a modality independent elastography (MIE) method) within the context of a pre-clinical breast cancer system. The elasticity results have shown good correlation with independent mechanical testing. Furthermore, MIE has been successfully utilized to localize and characterize lesions in both phantom experiments and simulation experiments with clinical data. However, the repeatability of this method has not been substantially characterized in previous work. The goal of this study is to evaluate voxel-level repeatability of MIE in a pre-clinical model of breast cancer. Bland-Altman analysis of co-registered repeat MIE scans in this preliminary study showed a repeatability index of 21.2% +/- 4.3% (percent of maximum stiffness) at the voxel level. As opposed to many reports in the magnetic resonance elastography (MRE) literature that speak to repeatability measures of the bulk organ, these results establish MIE repeatability at the voxel level; i.e., the repeatability of locally-defined mechanical property measurements over the tumor volume.

9417-4, Session 1

Nanoscale structural and chemical imaging of single bacterial cells for assessment of antibiotic resistance effects

Boyin Liu, Jiayao Li, Yeonuk Kim, Jing Fu, Monash Univ. (Australia)

Antibiotic resistance is a major risk to human health, and effective methods are highly expected to assess the cellular responses during and after antibiotics loading. We have been developing a set of innovative nanoengineering approaches, including Focused Ion Beam (FIB) and Atomic Force Microscopy (AFM), to probe multi-drug resistant strain Klebsiella pneumonia and examine the cellular responses after it was exposed to the "last-line" antibiotics. By iteratively removing slices of thickness of 25 nm with FIB, high magnification 2D images can be acquired by Scanning Electron Microscopy (SEM) at 2 nm resolution. 3D models of both cell envelope and cytoplasm regions containing nucleoid and ribosome were reconstructed from these serial images. The 3D volume containing nucleoid and ribosome was significantly smaller, and more than 200% protrusions per unit surface area on the cell envelope were observed in the curvature analysis after treatment. AFM probing beneath the bacterial cell wall was achieved for the first time, after removing layers of predefined thickness in the order of 100 nm on the target bacterial cells with FIB milling. The results revealed increased stiffness occurring in both surface and interior regions of the treated cells, suggesting loss of integrity of the outer membrane from polymyxin treatments. Further engineering development allows automated data acquisition and analysis, to provide a unique platform for assessment of antibiotic effects to combat the increasing threat of multidrug-resistant bacteria.

9417-5, Session 1

A hand-held EPR scanner for transcutaneous oximetry

Periannan Kuppusamy, Dartmouth College (United States)

Skin oxygenation is an important prognostic factor for the treatment of chronic wounds, skin cancer, diabetes side effects, and limb amputation. Currently, the only approved method for measuring oxygen concentration (oximetry) in the human skin is based on Clarke-type electrodes directly attached to the skin. Nevertheless, his technique has many limitations, making it unattractive for standard medical practice. Oximetry, using electron paramagnetic resonance (EPR), is an emerging method that is based on the effect of molecular oxygen on the spin-spin relaxation time (T2) of paramagnetic species. The problem with EPR, however, is that it requires the use of a large homogenous static magnetic field source and large equipment, making it unattractive for clinical practice. We present an alternative approach that makes use of a miniature permanent magnet, combined with a small microwave resonator, to enable the acquisition of EPR signals including the oxygen-dependent T2 of the paramagnetic species placed on the skin. The novelty of this instrumentation is that it consists of a hand-held, modular, cylindrical probehead with overall dimensions of 35-dia. x 24-mm length and 150-g weight. The probehead includes a Halbach array of 16 pieces (4x4x8 mm3) of Co-Sm permanent magnet and a loop-gap resonator (2.24 GHz). Initial measurements using a Hahn-echo pulse sequence (averaged 800 times in 20 ms) showed an SNR of 2.5 compared to 5.4 in a homogenous magnet under identical settings. Further work is in progress to improve the performance of the probehead and to optimize the hand-held system for clinical use.

9417-6, Session 2

Multi-atlas segmentation for abdominal organs with Gaussian mixture models

Ryan P. Burke, Zhoubing Xu, Christopher P. Lee, Rebeccah B. Baucom, Benjamin K. Poulose, Richard G. Abramson, Bennett A. Landman, Vanderbilt Univ. (United States)

Abdominal organ segmentation with clinically acquired computed tomography (CT) is drawing increasing interest in the medical imaging community. Gaussian mixture models (GMM) have been extensively used through medical segmentation, most notably in the brain for cerebrospinal fluid / gray matter / white matter differentiation. Because abdominal CT exhibit strong localized intensity characteristics, GMM have recently been incorporated in multi-stage abdominal segmentation algorithms. In the context of variable abdominal anatomy and rich algorithms, it is difficult to assess the marginal contribution of GMM. Herein, we characterize the efficacy of an a posteriori framework that integrates GMM of organ-wise intensity likelihood with spatial priors from multiple target-specific registered labels. In our study, we first manually labeled 100 CT images. Then, we assigned 40 images to use as training data for constructing target-specific spatial priors and intensity likelihoods. The remaining 60 images were evaluated as test targets for segmenting 12 abdominal organs. The overlap between the true and the automatic segmentations was measured by Dice similarity coefficient (DSC). A median improvement of 145% was achieved by integrating the GMM intensity likelihood against the specific spatial prior. The proposed framework opens the opportunities for abdominal organ segmentation by efficiently using both the spatial and appearance information from the atlases, and creates a benchmark for large-scale automatic abdominal segmentation.

9417-7, Session 2

Quantification of esophageal wall thickness in CT using atlas-based segmentation technique

Jiahui Wang, Univ. of Maryland Medical Ctr. (United States); Min Kyu Kang, Univ. of Maryland, Baltimore (United States) and Yeungnam Univ. (Korea, Republic of); Seth Kligerman, Univ. of Maryland School of Medicine (United States); Wei Lu, The Univ. of Maryland (United States)

Esophageal wall thickness is an important predictor of esophageal cancer and tumor response to the radiation therapy. In this study, we developed an automated pipeline for quantification of esophageal wall thickness from computerized tomography (CT). We first segment the esophagus using a multi-atlas-based segmentation scheme. The esophagus in each atlas CT is manually segmented to create a label map. Using image registration, all of the atlases are aligned to the imaging space of the target CT. The deformation field from the registration is applied to the label maps to warp them to the target space. A weighted majority-voting label fusion is employed to create the segmentation of esophagus. Finally, we use a CT value thresholding technique to exclude the lumen from the esophagus and measure the esophageal wall thickness. The developed method was tested on a dataset of 10 CT scans, including 4 esophageal cancer patients and 6 normal controls. The mean absolute distance (MAD) between the segmented esophagus and the reference standard is employed to evaluate the segmentation results. Our method achieved a mean MAD of 3.53 mm for all the cases. The mean esophageal wall thickness of cancer patients and normal controls is 8.45 mm and 6.83 mm, respectively. This result confirmed the hypothesis that the esophageal wall thickness is increased with esophageal cancer. We conclude that the proposed method can perform quantitative analysis of esophageal wall thickness and would be useful for tumor detection and tumor response evaluation of esophageal cancer.

9417-8, Session 2

Fully automatic algorithm for segmenting full human diaphragm in non-contrast CT Images

Elham Karami, Western Univ. (Canada) and Robarts Research Institute (Canada); Stewart Gaede, London Health Sciences Ctr. (Canada) and Western Univ. (Canada); Ting-Yim Lee, Lawson Health Research Institute (Canada) and Robarts Research Institute (Canada) and Western Univ. (Canada); Abbas Samani, Western Univ. (Canada) and Robarts Research Institute (Canada)

The diaphragm is a sheet of muscle which separates the thorax from the abdomen and acts as the most important muscle of the respiratory system. As such, an accurate segmentation of the diaphragm, not only provides necessary information for functional analysis of the respiratory system, but also can be used for locating other abdominal organs such as the liver. However, diaphragm segmentation is extremely challenging in non-contrast CT images due to the diaphragm's similar appearance to other abdominal organs. In this paper, we present a fully automatic algorithm for diaphragm segmentation in non-contrast CT images. The method is mainly based on a priori knowledge about the human diaphragm anatomy. The diaphragm domes are in contact with the lungs and the heart while its circumference runs along the lumbar vertebrae of the spine as well as the inferior border of the ribs and sternum. As such, the diaphragm can be delineated by segmentation of these organs followed by connecting relevant parts of their outline properly. More specifically, the bottom surface of the lungs and heart, the spine borders and the ribs are delineated, leading to a set of scattered points which represent the diaphragm's geometry. Next, a B-spline filter is used to find the smoothest surface which pass through these points. This algorithm was tested on a non-contrast CT image of a lung cancer patient. The results indicate that there is an average Hausdorff distance of 2.45 mm between the automatic and manually segmented diaphragms which implies a favorable accuracy.

9417-9, Session 2

Progress toward automatic classification of human brown adipose tissue using biomedical imaging

Aliya Gifford, Vanderbilt Univ., Institute of Imaging Science (United States); Theodore F. Towse, Vanderbilt Univ. School of Medicine (United States) and Vanderbilt Univ., Institute of Imaging Science (United States); Ronald C. Walker, Tennessee Valley Healthcare System (United States); Malcom J. Avison, Vanderbilt Univ., Institute of Imaging Science (United States) and Vanderbilt Univ. School of Medicine (United States); Edward B. Welch, Vanderbilt Univ., Institute of Imaging Science (United States)

Brown adipose tissue (BAT) has recently been discovered in adult humans, and plays an important role in obesity and the pathogenesis of metabolic syndrome. Interest in studying BAT is increasing, but in order to quantify BAT volume in a single measurement or detect changes in BAT over the time course of a longitudinal experiment, BAT needs to first be reliably differentiated from surrounding tissue. Although the uptake of the radiotracer 18F-Fluorodeoxyglucose (18F-FDG) in adipose tissue on positron emission tomography (PET) scans following cold exposure is accepted as an indication of BAT, it is not a definitive indicator and to date there exists no standardized method for segmenting BAT. Consequently, there is a strong need for robust automatic classification of BAT based on properties measured with biomedical imaging. In this study we develop an automated segmentation method based on both fat-water MRI and PET/CT scans acquired on ten healthy adult subjects.

9417-10, Session 3

A Bloch-McConnell simulator with pharmacokinetic modeling to explore accuracy and reproducibility in the measurement of hyperpolarized Pyruvate

Christopher M. Walker, James A. Bankson, The Univ. of Texas M.D. Anderson Cancer Ctr. (United States)

Magnetic resonance imaging (MRI) of hyperpolarized (HP) agents has the potential to probe in-vivo metabolism with sensitivity and specificity that was not previously possible. Biological conversion of HP agents specifically for cancer has been shown to correlate to presence of disease, stage and response to therapy. For such metabolic biomarkers derived from MRI of hyperpolarized agents to be clinically impactful, they need to be validated and well characterized. However, imaging of HP substrates is distinct from conventional MRI, due to the non-renewable nature of transient HP magnetization. Moreover, due to current practical limitations in generation and evolution of hyperpolarized agents, it is not feasible to fully characterized measurement and processing of hyperpolarized agents experimentally. In this work we use a custom Bloch-McConnell simulator to characterize the performance of specific magnetic resonance spectroscopy sequences over a range of biological conditions. We performed numerical simulations to evaluate the effect of sequence parameters over a range of chemical conversion rates. Each simulation was analyzed repeatedly with the addition of noise in order to determine the accuracy and reproducibility of measurements. The measured chemical conversion rate varied widely as a function of sequence parameters for a given actual conversion rate, and sequence parameters that yielded the most accurate measurement varied according to the actual conversion rate. This novel application of the Bloch-McConnell formalism revealed surprising sequence dependencies and will assist in the further optimization of sequences for the measurement of HP agents.

9417-11, Session 3

Fat-water MRI is sensitive to local adipose tissue inflammatory changes in a diet-induced obesity mouse model at 15T

Henry H. Ong, Vanderbilt Univ. (United States); Corey Web, Marnie L. Broderick, Alyssa Hasty, Vanderbilt Univ. School of Medicine (United States); John C. Gore, Vanderbilt Univ. Medical Ctr. (United States); Edward B. Welch, Vanderbilt Univ. (United States)

INTRODUCTION:
In obesity, fat-water MRI (FWMRI) methods provide valuable information about adipose tissue (AT) distribution. AT is known to undergo complex metabolic and endocrine changes in association with chronic inflammation including iron overloading. Here, we investigate the potential for quantitative FWMRI parameters (fat signal fraction (FSF), local frequency offset, and T2*) to be sensitive to AT inflammatory changes in an established diet-induced obesity mouse model.

METHODS:
Male C57BL/6J mice were placed on a low fat (LFD) or a high fat diet (HFD). 3D multi- gradient-echo MRI at 15.2T was performed at baseline, 4, 8, 12, and 16 weeks after diet onset. A 3D fat-water separation algorithm and additional processing was used to generate FSF, local frequency offset, and T2* maps. We examined these parameters in perirenal AT ROIs from HFD and LFD mice.

RESULTS:
The data suggest that FSF, local frequency offset, and T2* can differentiate time course behavior between inflamed and control AT (increasing FSF, decreasing local frequency offset, increasing + decreasing T2*). The biophysical mechanisms of these observed changes are not well understood and require further study.

CONCLUSIONS:
To the best of our knowledge, we report the first evidence that quantitative FWMRI can provide biomarkers sensitive to AT inflammation, and that FWMRI has the potential for longitudinal non-invasive assessment of AT dysfunction in obesity.

**Conference 9417: Biomedical Applications
in Molecular, Structural, and Functional Imaging**

9417-12, Session 3

Susceptibility weighted imaging of stroke brain in response to normobaric oxygen (NBO) therapy

Iris Y. Zhou, Phillip Z. Sun, Takahiro Igarashi, Yingkun Guo, Massachusetts General Hospital (United States)

The neuroprotective effect of oxygen leads to recent interest in normobaric oxygen (NBO) therapy after acute ischemic stroke. However, the mechanism remains unclear and inconsistent outcomes were reported in human studies. Because NBO aims to improve brain tissue oxygenation by enhancing oxygen delivery to ischemic tissue, monitoring the oxygenation level changes in response to NBO becomes necessary to elucidate the mechanism and to assess the efficacy. Susceptibility weighted imaging (SWI) which provides a new MRI contrast by combining the magnitude and phase images is fit for purpose. SWI is sensitive to deoxyhemoglobin level changes and thus can be used to evaluate the cerebral metabolic rate of oxygen. In this study, SWI was used for in vivo monitoring of oxygenation changes in a rat model of permanent middle cerebral artery occlusion (MCAO) before, during and after 30 min of NBO treatment. Regions of interest in ischemic core, penumbra and contralateral normal area were generated based on diffusion-weighted imaging and perfusion imaging. Significant differences in SWI indicating different oxygenation levels were generally found: contralateral normal > penumbra > ischemic core. Ischemic core showed insignificant increase in oxygenation during NBO and returned to pre-treatment level after termination of NBO. Meanwhile, the oxygenation levels slightly increased in contralateral normal and penumbra regions during NBO and significantly decreased to a level lower than pre-treatment after termination of NBO, indicating secondary metabolic disruption upon the termination of transient metabolic support from oxygen. Further investigation of NBO effect combined with reperfusion is necessary while SWI can be used to detect hemorrhagic transformation after reperfusion.

9417-13, Session 3

Quantification of in vivo pH-weighted amide proton transfer (APT) MRI in acute ischemic stroke

Phillip Z. Sun, Iris Y. Zhou, Takahiro Igarashi, Yingkun Guo, Massachusetts General Hospital (United States) and Harvard Medical School (United States)

Amide proton transfer (APT) imaging is a specific form of chemical exchange saturation transfer (CEST) MRI that probes the pH-dependent amide proton exchange. The endogenous APT MRI is sensitive to tissue acidosis, which may complement the commonly used perfusion and diffusion scans for characterizing heterogeneous ischemic tissue damage. Whereas the saturation transfer asymmetry analysis (MTRasym) may reasonably compensate for direct RF saturation, in vivo MTRasym is however, susceptible to an intrinsically asymmetric shift (MTR'asym). Specifically, the reference scan for the endogenous APT MRI is 7 ppm upfield from that of the label scan, and subjects to concomitant RF irradiation effects, including nuclear overhauser effect (NOE)-mediated saturation transfer and semisolid macromolecular magnetization transfer. As such, the commonly used asymmetry analysis could not fully compensate for such slightly asymmetric concomitant RF irradiation effects, and MTRasym has to be delineated in order to properly characterize the pH-weighted APT MRI contrast. Given that there is very little change in relaxation time immediately after ischemia and the concomitant RF irradiation effects only minimally depends on pH, the APT contrast can be obtained as the difference of MTRasym between the normal and ischemic regions. Thereby, the endogenous amide proton concentration and exchange rate can be solved using a dual 2-pool model, and the in vivo MTR'asym can be calculated by subtracting the solved APT contrast from asymmetry analysis (i.e., MTR'asym =MTRasym-APTR). In addition, MTR'asym can be quantified using the classical 2-pool exchange model. In

sum, our study delineated the conventional in vivo pH-sensitive MTRasym contrast so that pH-specific contrast can be obtained for imaging ischemic tissue acidosis.

9417-14, Session 3

A rapid Look-Locker imaging sequence for quantitative tissue oximetry

Rohini Vidya Shankar, Vikram D. Kodibagkar, Arizona State Univ. (United States)

Tissue oximetry studies using magnetic resonance imaging (MRI) are increasingly contributing to advances in the imaging, treatment, and surveillance of cancer. The non-invasive measurement of tissue oxygenation (pO2) may facilitate a better understanding of the pathophysiology and prognosis of numerous diseases, particularly in the assessment of the extensive hypoxic regions associated with cancerous lesions. The availability of tumor hypoxia maps could potentially help quantify and predict tumor response to intervention and radiation therapy. Several techniques have been developed for investigating the oxygen tension in tissues; The PISTOL (Proton Imaging of Siloxanes to map Tissue Oxygenation Levels) oximetry technique maps the T1 of administered hexamethyldisiloxane (HMDSO), which is an established 1H NMR pO2 reporter molecule, to subsequently monitor dynamic changes in the tissue pO2 (in response to intervention) at various locations. A HMDSO-selective Look-Locker imaging sequence with echo planar imaging (EPI) readout has been developed to enable faster PISTOL acquisitions. The new oximetry sequence incorporates the fast Look-Locker measurement method to enable T1, and hence, pO2 mapping of HMDSO in less than one minute. To demonstrate the application of this pulse sequence in vivo, 50 μL of neat HMDSO was administered to the thigh muscle of a healthy rat (Fischer F344, n=4). Dynamic changes in the mean pO2 of the thigh muscle were measured using both PISTOL and the developed LL oximetry sequence in response to oxygen challenge. Results demonstrate the efficacy of the new sequence in rapidly mapping the pO2 changes, leading to advances in fast quantitative 1H MR oximetry.

9417-15, Session 4

The rapid imaging renaissance: sparser samples, denser dimensions, and glimmerings of a grand unified tomography *(Keynote Presentation)*

Daniel K. Sodickson, New York Univ. School of Medicine (United States)

The need to resolve both structure and dynamics is a connecting theme across diverse areas of endeavor spanning multiple orders of magnitude in space and time. The task of imaging is to gather spatiotemporal information which can be organized into a coherent map. Tomographic imaging in particular involves the use of multiple projections, or other interactions of a probe (light, sound, etc) with a body, in order to determine cross-sectional information. Though the probes and the corresponding imaging modalities may vary, and though the methodology of particular imaging approaches is in constant ferment, the conceptual underpinnings of tomographic imaging have in many ways remained fixed for many decades. Recent advances in applied mathematics, however, have begun to roil this intellectual landscape. The advent of compressed sensing, anticipated in various algorithms dating back many years but unleashed in full theoretical force in the last decade, has changed the way imagers have begun to think about data acquisition and image reconstruction. The power of incoherent sampling and sparsity-enforcing reconstruction has been demonstrated in various contexts and, when combined with other modern fast imaging techniques, has enabled unprecedented accelerations of image acquisition. Perhaps more importantly, however, such approaches have spurred a shift in perspective, prompting us to focus less on nominal data sufficiency than on information content. Beginning with examples from MRI, then proceeding through

selected other modalities such as CT and PET, as well as multimodality combinations, this talk will explore the potential of newly evolving acquisition and reconstruction paradigms to change the way we do imaging in the lab and in the clinic.

9417-16, Session 4

Structured illumination multispectral optical imaging to assess brain function in a mouse model of focal traumatic brain injury

David Abookasis, Boris Volkov, Ariel Univ. (Israel)

The objective of this study was to use multispectral imaging based on near-infrared structured light illumination to quantitatively assess brain function during focal traumatic brain injury (fTBI). fTBI was conducted upon five anaesthetized mice by weight-drop method; ~50 gr steel cylindrical rod was dropped upon mouse intact head through a 90 cm long metal tube producing an impact of 4500 g cm. Structured illumination at several near-infrared wavelengths from 600 to 1000nm and at two different spatial frequencies were projected before, during, and up to 1 h after the onset of injury. Diffuse reflected light was recorded by a CCD camera positioned perpendicular to the mouse head and data processing was performed off-line. Following data analysis, we were able to concurrently show a series of hemodynamic and morphologic changes over time including higher deoxyhemoglobin, reduction in oxygen saturation, cell swelling, etc., in comparison with baseline measurements. Specifically, a t-test indicates a substantial decrease in oxyhemoglobin (HbO2) concentration and tissue oxygen saturation (StO2) post-injury ($p < 0.01$ and $p < 0.001$, respectively). Results from this animal model demonstrate the potential of using multispectral imaging based structured illumination to follow and map brain tissue optical and physiological properties during brain injury in a simple, noninvasive, and noncontact manner.

9417-17, Session 4

Predicting stroke outcome using DCE-CT measured blood velocity

Jaap Oosterbroek, Edwin Bennink, Jan Willem Dankbaar, Alexander D. Horsch, Max A. Viergever, Birgitta K. Velthuis, Hugo W. A. M. de Jong, Univ. Medical Ctr. Utrecht (Netherlands)

CT plays an important role in diagnosis of acute stroke patients. CT-angiography (CTA) can image the intravascular lumen and occlusions, and dynamic contrast enhanced CT (DCE-CT) allows for estimation of local tissue perfusion. However, hemodynamic information of the large intracranial vessels can also be obtained from DCE-CT data and may contain valuable diagnostic information. Here we describe a novel method to estimate intravascular blood velocity (IBV) in cerebral vessels using DCE-CT data, that can be used to predict stroke outcome. To this end, DCE-CT scans from 34 patients with isolated M1 occlusions were included retrospectively from a large database. Gaussians fitted to the data yielded the time-to-peak (TTP) and cerebral-blood-volume (CBV). IBV was computed by taking the inverse of the TTP gradient magnitude. Voxels with a CBV of at least 10% of the CBV found in the arterial input function were considered part of a vessel. Mid-sagittal planes were drawn manually and averages of the IBV over all vessel-voxels (arterial and venous) were computed for each hemisphere. Mean-hemisphere IBV differences, mean-hemisphere TTP differences, or hemisphere vessel volume differences were used to differentiate between patients with good and bad outcome using ROC analysis. AUCs from the ROC for IBV, TTP, and vessel volume were 0.80, 0.67 and 0.62 respectively. In conclusion, IBV was found to be a better predictor of patient outcome than the parameters used to compute it and may be a promising new parameter for stroke diagnosis.

9417-18, Session 4

Marker-less multi-frame motion tracking and compensation in PET-brain imaging

Clifford Lindsay, Joyeeta M. Mukherjee, Karen Johnson, Univ. of Massachusetts Medical School (United States); Patrick Olivier, Xiyun Song, Ling-Xiong Shao, Philips Healthcare (United States); Michael A. King, Univ. of Massachusetts Medical School (United States)

In PET brain imaging, patient motion can contribute significantly to the degradation of image quality potentially leading to diagnostic and therapeutic problems. To mitigate the image artifacts resulting from patient motion, motion must be detected and tracked then provided to a motion correction algorithm. Existing techniques to track patient motion fall into one of two categories: 1) image-derived approaches [1] and 2) external motion tracking (EMT) [2]. Typical EMT requires patients to have markers in a known pattern on a rigid too attached to their head, which are then tracked by expensive and bulky motion tracking camera systems or stereo cameras. This has made marker-based EMT unattractive for routine clinical application. Our main contributions are the development of a marker-less motion tracking system that uses low-cost, small depth-sensing cameras which can be installed in the bore of the imaging system. Our motion tracking system does not require anything to be attached to the patient and can track the rigid transformation (6-degrees of freedom) of the patient's head at a rate 60 Hz. We show that our method can not only be used in with Multi-frame Acquisition (MAF) PET [3] motion correction, but precise timing can be employed to determine only the necessary frames needed for correction. This can speeds up reconstruction by eliminating the unnecessary subdivision of frames.

9417-19, Session 5

Towards an automated selection of spontaneous co-activity maps in functional magnetic resonance imaging

Marion Sourty, Laurent Thoraval, Daniel Roquet, Jean-Paul Armspach, Univ. de Strasbourg (France); Jack Foucher, Univ. de Strasbourg (France) and Hôpitaux Univ. de Strasbourg (France)

Functional magnetic resonance imaging allows to assess large scale functional integration of the brain. One of the leading techniques to extract functionally relevant networks is spatial independent component analysis (ICA). Spatial ICA separates independent spatial sources, many of whom are noise or imaging artifacts, whereas some do correspond to functionally relevant Spontaneous co-Activity Maps (SAMs). For research purposes, ICA is generally performed on group data. This strategy is well adapted to uncover commonly shared networks, e.g. resting-state networks, but fails to capture idiosyncratic functional networks which may be related to pathological activity, e.g. epilepsy, hallucinations. To capture these subject specific networks, ICA has to be applied to single subjects using a large number of components, from which a tenth are SAMs. Up to now, SAMs have to be selected manually by an expert based on predefined criteria. We aim to semi-automate the selection process in order to save time. To this end, some approaches have been proposed but none with the near 100 % sensitivity required for clinical purposes. In this paper, we propose a computerized version of the SAM's criteria used by experts, based on frequential and spatial characteristics of functional networks. Here we present a pre-selection method and its results at different resolutions, with different scanners or imaging sequences. While preserving a near 100 % sensitivity, it allows an average of 70 % reduction of components to be classified which save 55% of experts' time. In comparison, group ICA fails to detect about 25% of the SAMs.

9417-20, Session 5

Cortical activities of single-trial P300 amplitudes modulated by memory load using simultaneous EEG-fMRI

Qiushi Zhang, Xiaojie Zhao, Li Yao, Beijing Normal Univ. (China)

The functional magnetic resonance imaging (fMRI) researches on working memory have found that activation of cortical areas appeared dependent on memory load, and event-related potentials (ERP) studies have demonstrated that amplitudes of P300 decreased significantly when working memory load increased. However, the cortical activities related with P300 amplitudes under different memory loads remains unclear. Joint fMRI and EEG analysis which fusions the time and spatial information in simultaneous EEG-fMRI recording can reveal the regional activation at each ERP time point. In this paper, we firstly used wavelet transform to extract the P300 amplitudes at a single-trial level in a digital N-back task by simultaneous EEG-fMRI recording as the ERP feature sequences. Then the feature sequences in 1-back condition and 3-back condition were introduced into general linear model (GLM) separately as parametric modulations to compare the cortical activations under different memory loads. The results showed that the P300 amplitudes of average ERPs in 3-back significantly decreased than that in 1-back, and the activations induced by ERP feature sequences in 3-back also significantly decreased than that in the 1-back, including the insular, anterior cingulate cortex, inferior frontal gyrus, and medial frontal gyrus, which were relevant to the storage, monitoring, and manipulation of information in working memory task. Moreover, the differences in the activations caused by single-trial P300 amplitudes showed a positive correlation with the differences in behavioral performance. These findings demonstrated the locations of P300 amplitudes differences modulated by memory load and its relationship with the behavioral performance.

9417-21, Session 5

Nonlinear functional connectivity network recovery in the human brain with mutual connectivity analysis (MCA): convergent cross-mapping and non-metric clustering

Axel Wismüller, Univ. of Rochester Medical Ctr. (United States); Anas Z Abidin, Univ of Rochester Medical Ctr (United States); Adora M. D'Souza, Xixi Wang, Susan K. Hobbs, Univ. of Rochester Medical Ctr. (United States); Lutz Leistritz, Institute of Medical Statistics, Computer Sciences, and Documentation, Friedrich Schiller University (Germany); Mahesh B. Nagarajan, Univ. of Rochester Medical Ctr. (United States)

We explore a computational framework for functional connectivity analysis in resting-state functional MRI (fMRI) data acquired from the human brain for recovering the underlying network structure and understanding causality between network components. Termed mutual connectivity analysis (MCA), this framework involves two steps, the first of which is to evaluate the pair-wise cross-prediction performance between fMRI pixel time series within the brain. In a second step, the underlying network structure is subsequently recovered from the affinity matrix using non-metric network clustering approaches, such as the so-called Louvain method. Finally, we use convergent cross-mapping (CCM) to study causality between different network components. We demonstrate our MCA framework in the problem of recovering the motor cortex network associated with hand movement from resting state fMRI data. Results are compared with a ground truth of active motor cortex regions as identified by a task-based fMRI sequence involving a finger-tapping stimulation experiment. Our results regarding causation between regions of the motor cortex revealed a significant directional variability and were not readily interpretable in a consistent manner across subjects. However, our results on whole-slice fMRI analysis

demonstrate that MCA-based model-free recovery of regions associated with the primary motor cortex and supplementary motor area are in close agreement with localization of similar regions achieved with a task-based fMRI acquisition. Thus, we conclude that our MCA methodology can extract and visualize valuable information concerning the underlying network structure between different regions of the brain in resting state fMRI.

9417-22, Session 5

Comparing consistency of R2* and T2*-weighted BOLD analysis of resting state fetal fMRI

Sharmishtaa Seshamani, Ania Blazejewska, Christopher Gatenby, Susan Mckown, Jason Caucutt, Manjiri Dighe, Colin Studholme, Univ. of Washington (United States)

Understanding when and how resting state brain functional activity begins in the human brain is an increasing area of interest in both basic neuroscience and in the clinical evaluation of the brain during pregnancy and after premature birth. Although fMRI studies have been carried out on pregnant women since the 1990's, reliable mapping of brain function in utero is an extremely challenging problem due to the unconstrained fetal head motion. Recent studies have employed scrubbing to exclude parts of the time series and whole subjects from studies in order to control the confounds of motion. Fundamentally, even after correction of the location of signals due to motion, signal intensity variations are a fundamental limitation, due to coil sensitivity and spin history effects. An alternative technique is to use a more parametric MRI signal derived from multiple echoes that provides a level of independence from basic MRI signal variation. Here we examine the use of R2* mapping combined with slice based multi echo geometric distortion correction for in-utero studies. The challenges for R2* mapping arise from the relatively low signal strength of in-utero data. In this paper we focus on comparing activation detection in-utero using T2W and R2* approaches. We make use of a subset of studies with relatively limited motion to compare the activation patterns without the additional confound of significant motion. Results at different gestational ages indicate comparable agreement in many activation patterns when limited motion is present, and the detection of some additional networks in the R2* data, not seen in the T2W results.

9417-23, Session 5

Robust motion correction and outlier rejection of in vivo functional MR images of the fetal brain and placenta during maternal hyperoxia

Wonsang You, Ahmed Serag, Children's National Medical Ctr. (United States); Iordanis E. Evangelou, Children's National Medical Ctr. (United States) and George Washington Univ. (United States); Nickie Niforatos-Andescavage, Children's National Medical Ctr. (United States); Catherine Limperopoulos, Children's National Medical Ctr. (United States) and George Washington Univ. (United States)

Subject motion is a major challenge in blood oxygenation level dependent (BOLD) functional magnetic resonance imaging (fMRI) studies of the brain, and has been addressed by diverse motion correction tools based on rigid body registration. However, traditional tools often fail to achieve acceptable performance in such complex anatomy, contacting multiple organs with high degree of motion, such as in-vivo functional imaging data of the fetal brain and placenta. Earlier studies have attempted to exclude volumes with high motion that are not compensated by motion correction, which may lead to an irrecoverable loss of data. In this paper, we propose an advanced

motion correction and volume outlier rejection method to correct severe motion artifacts without unnecessary data loss. The method is customized to the experimental paradigm by applying preprocessing steps separately to each phase as well as to each moving object which is distinct according to its characteristic pattern of movement. It also automatically excludes volumes with high motion by computing the occurrence probability of outliers triggered by object motion which reflects the temporal variation of BOLD signals as well as motion-oriented image mismatching. In addition, all the missing data are estimated from signals averaged over an ROI on the basis of the sinusoidal regression model with Gaussian uncertainty in order to enable advanced time series analyses in post-processing steps. Experimental results demonstrate that the proposed method is effective to enhance the performance of motion correction in maternal hyperoxia fMRI data of fetal brain and placenta without deleterious data loss.

9417-24, Session 6

Segmentation of microcystic macular edema in Cirrus OCT scans with an exploratory longitudinal study

Emily K. Swingle, The Ohio State Univ. (United States); Andrew Lang, Aaron Carass, Omar Al-Louzi, Johns Hopkins Univ. (United States); Shiv Saidha, Department of Neurology, The Johns Hopkins University School of Medicine (United States); Jerry L. Prince, Peter A. Calabresi, Johns Hopkins Univ. (United States)

Microcystic macular edema (MME) is a term used to describe pseudocystic spaces in the inner nuclear layer (INL) of the human retina. Originally observed in multiple sclerosis (MS) patients, it has since been observed in a spectrum of other disorders. The processes that lead to MME formation and their change over time have yet to be explained sufficiently, and the small rate at which MME occurs within such diverse patient groups makes the identification and consistent quantification of this pathology important for developing patient-specific prognoses. MME can be observed in optical coherence tomography (OCT) scans of the retina as pseudocysts. Pseudocysts can be readily identified in higher signal-to-noise ratio (SNR) images, however pseudocysts can be indistinguishable from noise in lower SNR scans. In this work, we expand upon our earlier MME identification methods on Spectralis OCT scans to handle noisier Cirrus OCT scans. Our approach uses a random forest classifier, trained on manual segmentation of ten subjects, to automatically detect MME. The algorithm has a true positive rate for MME identification of 0.95 and a Dice score of 0.79. We include a preliminary longitudinal study of three patients over four to five years to explore the nature of MME. The patients with relapsing-remitting MS and neuromyelitis optica appear to have dynamic pseudocyst volumes, while the volume appears stable in the patient with primary progressive MS.

9417-25, Session 6

Estimation of tissue optical parameters with hyperspectral imaging and spectral unmixing

Guolan Lu, Xulei Qin, Dongsheng Wang, Georgia Zhuo Chen, Baowei Fei, Emory Univ. (United States)

Early detection of oral cancer and its curable precursors remains the best way to ensure patient survival and improved quality of life. Hyperspectral imaging (HSI) holds the potential for noninvasive early detection of oral cancer. The quantification of tissue chromophores by spectral unmixing of hyperspectral images could provide insights for evaluating cancer progression. In this study, non-negative matrix factorization has been applied for decomposing hyperspectral images into physiologically meaningful chromophore concentration maps. The approach has been validated in computer-simulated hyperspectral images and in tumor hyperspectral images from a head and neck cancer animal model.

9417-26, Session 6

Ultrasound-switchable fluorescence imaging in deep tissue via a sensitive USF system and NIR contrast agents

Bingbing Cheng, The Univ. of Texas at Arlington (United States) and The Univ. of Texas Southwestern Medical Ctr. at Dallas (United States); Yanbo Pei, Ming-Yuan Wei, The Univ. of Texas at Arlington (United States); Venugopal Bandi, Univ. of North Texas (United States); Kytai T. Nguyen, Yi Hong, The Univ. of Texas at Arlington (United States); Francis D'Souza, Univ. of North Texas (United States); Baohong Yuan, The Univ. of Texas at Arlington (United States)

We recently developed a new imaging technique—ultrasound-switchable fluorescence (USF), aiming to achieve relatively high resolution in centimeter-deep tissue. The basic idea is using a focused ultrasound wave to externally and locally switch on and off USF contrast agents in a small volume (close to or even smaller than the ultrasound focal volume). Based on excellent NIR contrast agents that are synthesized by thermo-sensitive polymers and switchable-fluorescent dyes, and a sensitive USF system, this technique has its unique advantages over other imaging techniques: 1) deep tissue (>> 1 mm), 2) high resolution (micron-size), 3) high signal-to-noise ratio (SNR), and 4) multi-color. These advantages are great helpful in revealing micro-information such as: microcirculation or microstructures in sub-centimeter or centimeter tissue for studying human health and disease. Excellent USF contrast agents and USF systems have been developed. High SNR and multi-color USF images have been successfully achieved in tissue (thickness: ~ 10 mm) using this system with two different USF contrast agents based on ICG and ADPDICA. The peak emission wavelength for ADPDICA and ICG are 720 nm and 830 nm, respectively. In addition, this technique is also successfully used to image mice organs, such as liver and spleen.

9417-27, Session 6

An automatic labeling bifurcation method for intracoronary optical coherence tomography images

Maysa M. G. Macedo, Univ. de São Paulo Medical School (Brazil); Celso H. Takimura, Pedro A. Lemos, Univ. of Sao Paulo Medical School (Brazil); Marco A. Gutierrez, Univ. of Sao Paulo Medical School (Brazil)

IIntravascular optical coherence tomography (IV-OCT) is a catheter-based imaging modality that provides a feasible method to visualize coronary plaques on the microscopic scale.

The quantification of structures present on the vessel-wall using IV-OCT can assist in diagnosis, but requires dedicated software. To this end, several computational applications have been developed for lumen segmentation and plaque characterization. However, few studies have focused on vessel branching.

The regions where vessels divide, bifurcation regions, are a critical vascular location and play a relevant role in the progression of atherosclerosis. The study of this disease could be advanced by the identification of these regions. In this context, this paper describes a computational method to classify IV-OCT frames as belonging to the bifurcation region or not. The input to the proposed classification method is a sequence of frames taken during pullback, to which an automatic lumen segmentation is applied. One hundred and four features are extracted from the detected lumen contours and a set of the best features and their respective weights are determined by the method of multiple forward regression orthogonal least squares. A linear combinations of the selected features and their weights are used to form the classifier. Nine datasets were processed, totaling 834 frames from

human coronary IV-OCT.

A cross-validation scheme was applied in order to evaluate the performance of the approach. The tests showed that the task of classifying bifurcations achieved a sensitivity of 86% and a specificity of 92%.

9417-28, Session 6

Optical coherence tomography (OCT) of a murine model of chronic kidney disease

Hsing-Wen Wang, Hengchang Guo, Univ. of Maryland, College Park (United States); Peter M. Andrews, Erik Anderson, Georgetown Univ. Medical Ctr. (United States); Yu Chen, Univ. of Maryland, College Park (United States)

Chronic Kidney Disease (CKD) is characterized by a progressive loss in renal function over time. Pathology can provide valuable insights into the progression of CKD by analyzing the status of glomeruli and the uriniferous tubules over time. Optical coherence tomography (OCT) is a new procedure that can analyze the microscopic structure of the kidney in a non-invasive manner. This is especially important because there are significant artifacts associated with excision biopsies and immersion fixation procedures. Recently, we have shown that OCT can provide real time images of kidney microstructure and Doppler OCT (DOCT) can image glomerular renal blood flow in vivo without administrating exogenous contrast agents. In this study, we used OCT to evaluate CKD in a model induced by intravenous Adriamycin injection into Munich-Wistar rats and a model of natural aging rats. We evaluated tubular density and tubular diameter from OCT images at several post-Adriamycin induction time points and compared them with conventional light microscopic histological imaging. Proteinurea and serum creatinine were used as physiological markers of the extent of CKD. Preliminary OCT results revealed changes in tubular density due to tubular necrosis and interstitial fibrosis within the first 4 weeks following Adriamycin injection. From week 4 to 8 after Adriamycin induction, changes in tubular density and diameter occurred due to both tubular loss and tubular dilation. The results suggest OCT can provide additional information about kidney histopathology in CKD. DOCT revealed reduced blood flow in some glomeruli probably as a consequence of focal glomerularsclerosis.

9417-29, Session 6

MicroCT and optical coherence tomography imagistic assessment of the dental roots adhesive

Cosmin Sinescu, Meda-Lavinia Negru?iu, Luminita Nica, Univ. of Medicine and Pharmacy Victor Babes Timisoara (Romania); Adrian Manescu, Univ. Politecnica delle Marche (Italy); Virgil-Florin Duma, Aurel Vlaicu Univ. of Arad (Romania) and Politehnica Univ. of Timisoara (Romania) and Univ. of West Timisoara (Romania); Adrian Gh. Podoleanu, Univ. of Kent (United Kingdom)

Several obturation methods are available today for the 3D filling of the root canal and there are several methods capable to evaluate the ability to seal apically the root canals. However, the common methods of investigation are invasive; they also lead to the destruction of the samples. If the sectioning differs slightly from the desired area, the investigation is non-conclusive regarding the microleakages. Also, although the use of cone-beam μCT appears to be most promising for endodontic purposes, its effective radiation doses are higher than with conventional intra-oral and panoramic imaging. In contrast, en face (ef) OCT proves to be efficient for the investigation of material defects of dental restorations, dental materials and and micro-leakage at the interfaces, where the penetration depth depends on the material. Therefore, ef OCT is proposed in this study as a potential tool for in vivo endodontic imaging. Twenty five recently extracted human maxillary molars, extracted for caries or periodontal reasons were selected

for this study. The pulp chambers were completely opened, the dental pulp was removed and the root canals were shaped. Silver nanoparticles were used in half of the samples in order to increase the scattering of the adhesive material in comparison with the dental roots walls. The sample teeth were then probed using Time Domain (TD) OCT working at 1300 nm. A synchrotron radiation X-Ray micro-CT experiment was also performed. The imagistic results pointed out the efficiency of the silver nanoparticle layer used in order to increase the scattering of the root canal adhesive scattering for the OCT non-invasive investigation. MicroCT allowed for obtaining qualitative data related to the depth penetration of the root canal adhesive into the dentin walls.

9417-30, Session 7

Initial testing of a 3D printed perfusion phantom using digital subtraction angiography

Rachel P. Wood, Parag Khobragade, Toshiba Stroke and Vascular Research Ctr. (United States) and Univ. at Buffalo (United States); Leslie Ying, Univ. at Buffalo (United States); Kenneth Snyder, David S. Wack, Daniel R. Bednarek, Stephen Rudin, Ciprian N. Ionita, Toshiba Stroke and Vascular Research Ctr. (United States) and Univ. at Buffalo (United States)

Perfusion imaging is the most applied modality for the assessment of acute stroke. Parameters such as Cerebral Blood Flow, Cerebral Blood volume and Mean Transit Time are used to distinguish the tissue infarct core and ischemic penumbra. Due to lack of standardization these parameters vary significantly between vendors and software even when provided with the same data set. There is a critical need to standardize the systems and make them more reliable. We have designed a uniform phantom to test and verify the perfusion systems. We implemented a flow loop with different flow rates (100, 150, 200, 250 ml/min) and injected the same amount of contrast. The images of the phantom were acquired using a Digital Angiographic system. Since this phantom is uniform, projection images obtained using DSA is sufficient for initial validation. To validate the phantom we measured the contrast concentration at three Regions of interest (arterial input, venous output, perfused area) and derived time density curves (TDC). We then calculated the maximum slope and area under the TDCs. We fitted the curves with a Gamma variate function as the noise was affecting the maximum slope calculations. The maximum slope calculated using the raw data and using the Gamma fit had a difference of 118.69% for the perfused area and 33.65% for the arterial input. The maximum slope calculated and areas under the curve were sensitive to the flow changes. We have created a systematic way to calibrate existing perfusion systems and assess their reliability.

9417-31, Session 7

Angiographic analysis for phantom simulations of endovascular aneurysm treatments with a new fully retrievable asymmetric flow diverter

Aradhana Yoganand, Rachel P. Wood, Toshiba Stroke and Vascular Research Ctr. (United States); Carlos Jimenez, Univ. de Antioquía (Colombia) and Toshiba Stroke and Vascular Research Ctr. (United States); Adnan H. Siddiqui, Kenneth Snyder, Swetadri Vasan Setlur Nagesh, Daniel R. Bednarek, Stephen Rudin, Robert Baier, Ciprian N. Ionita, Toshiba Stroke and Vascular Research Ctr. (United States)

Digital Subtraction Angiography (DSA) is the main diagnostic tool for intracranial aneurysms flow-diverter (FD) assisted treatment. Based on

qualitative contrast flow evaluation, interventionists decide on subsequent steps. We have developed a novel fully Retrievable Asymmetric Flow-Diverter (RAFD) that makes deployment, flexibility of repositioning and detachment easier and enables achievement of maximum flow diversion. The design offers a region for sufficient in-jet flow deflection causing minimum impairment to adjacent vessels. We tested the new RAFD using a flow-loop with aneurysm phantom having carotid-relevant physiological conditions. We positioned the deflection region at three locations: distally, medially and proximally to the aneurysm orifice and analyzed aneurysm dome flow using DSA derived maps for mean transit time (MTT) and bolus arrival times (BAT). Comparison between treated and untreated (control) maps quantified the effect of the RAFD positioning. This showed that placement of the stent and positioning of the patch at various positions, guided and optimized using DSA, greatly influenced the inflow jet and contrast bolus distribution inside the aneurysm. Average MTT, which is related to contrast presence in the aneurysm dome increased, indicating flow decoupling between the aneurysm and parent artery. Maximum effect was observed in the medial position (~75%). BAT maps which correlate well with inflow jet direction and magnitude also demonstrated magnitude reduction and jet dispersion which was recorded maximum (~50%) for the proximal placement. This study demonstrates the effective use of DSA data to guide the re-positioning of the RAFDs and optimize flow diversion.

9417-33, Session 7

Dynamic myocardial perfusion in a porcine balloon-induced ischemia model using spectral detector CT

Rachid Fahmi, Brendan L. Eck, Case Western Reserve Univ. (United States); Anas Fares, Univ. Hospitals of Cleveland (United States); Jacob Levi, Case Western Reserve Univ. (United States); Mani Vembar, Amar C. Dhanantwari, Philips Healthcare (United States); Hiram G. Bezerra, Univ. Hospitals Case Medical Ctr. (United States); David L. Wilson, Case Western Reserve Univ. (United States)

Myocardial CT perfusion (CTP) imaging is an application that should greatly benefit from spectral CT through the significant reduction of beam hardening (BH) artifacts using mono-energetic (monoE) image reconstructions. We used a prototype spectral detector CT (SDCT, Philips Healthcare) scanner and developed advanced processing tools (registration, segmentation, and deconvolution-based flow estimation) for quantitative myocardial CTP in a porcine ischemia model with partial coronary occlusion using a balloon catheter. The occlusion severity was adjusted with FFR measurements. The SDCT scanner is a single source, dual-layer detector system, which allows simultaneous acquisitions of low- and high-energy projections, hence enabling accurate projection-based material decomposition and effective reduction of BH-artifacts. In addition, the system eliminates partial scan artifacts with fast, full gantry rotation (0.27s) acquisitions. We computed myocardial blood flow (MBF in mL/min/100g) using MonoE images (50keV-to-120keV) and conventional 120kVp images. Comparing MBF maps at different keVs, we found that maps at 70keV were more uniform with a high flow-contrast-to-noise ratio (CNRf) between ischemic and normal territories. Quantitatively, we noticed a steady decrease in CNRf and an overestimation of mean-MBF for energies different than 70keV. Flow overestimation was also noticed with non BH-corrected 120kVp scans. An estimate of the read FFR value, eFFR, was estimated as the ratio between max-flow in an ischemic and that in a normal ROI. At FFR~0.7, the averaged mean-MBF was 77.42±16.68 and 30.52±12.26 at 70keV vs. 95.05±21.07(p=1.6e-06) and 27.51±10.28(p=0.35) at 120kVp in a normal and ischemic ROI, respectively. The mean eFFR was 0.58±0.12 at 70keV vs. 0.43±0.07(p=0.001) at 120kVp.

9417-34, Session 7

Low dose dynamic myocardial CT perfusion using advanced iterative reconstruction

Brendan L. Eck, Rachid Fahmi, Case Western Reserve Univ. (United States); Christopher Fuqua, Case Western Reserve Univ. (United States) and Philips Healthcare (United States); Mani Vembar, Amar C. Dhanantwari, Philips Healthcare (United States); Hiram G. Bezerra, Univ. Hospitals Case Medical Ctr. (United States); David L. Wilson, Case Western Reserve Univ. (United States)

Dynamic myocardial CT perfusion (CTP) can provide functional information for assessment of cardiovascular disease. However, x-ray dose in dynamic CTP is typically high, >10mSv. We compared the dose reduction potential of an advanced iterative reconstruction (IR) from Philips Healthcare (IMR), hybrid IR (iDose), and FBP. Dynamic CTP scans were obtained using a porcine model with balloon-induced ischemia in the LAD coronary to prescribed fractional flow reserve wire values (FFR=0.7). Images were acquired with 8cm coverage, 35-50 ECG-gated partial scans, 100kVp/100mAs, effective dose 16-23mSv. Low dose scans at 75mAs, 50mAs, and 25mAs were simulated using a projection-based noise simulator with detector noise (?abi?, Med Phys. 2013). Image HU (mean+/-sd), SNR, and CNR were obtained from ROIs in ischemic and healthy LV myocardium. Blood flow, flow SNR (fSNR), and flow CNR (fCNR) were obtained using our dynamic CTP analysis pipeline (Fahmi, SPIE Proc. 2014). Mean HUs were consistent across dose and reconstruction. At 25mAs, IMR showed highest quality (SNR=12.7), compared to iDose (10.4), and FBP (4.2). Blood flow (ml/min-100g) in FBP was increasingly over-estimated at reduced dose, from 100mAs (ischemic=71; normal=81) to 25mAs (145;113), where noise caused LAD flow to appear greater than healthy myocardium. Flow was consistent for iDose from 100mAs (64;76) to 50mAs (74;81), but over-estimated at 25mAs (101;93). IMR was consistent from 100mAs (52;67) to 25mAs (63;76). Images and flow maps of 100mAs FBP, 50mAs iDose, and 25mAs IMR showed clear ischemia. Advanced IR may enable dynamic CTP at significantly reduced dose, 4mSv or 25% of FBP protocols.

9417-78, Session 7

Improved factor analysis of dynamic PET images to estimate arterial input function and tissue curves

Debasis Mitra, Florida Institute of Technology (United States); Rostyslav Boutchko, Lawrence Berkeley National Lab. (United States); Hui Pan, Florida Institute of Technology (United States); William Jagust, Grant T. Gullberg, Lawrence Berkeley National Lab. (United States)

Factor analysis of dynamic structures (FADS) is a methodology of extracting time-activity curves (TACs) for corresponding different tissue types from noisy dynamic images. The challenges of FADS include long computation time and sensitivity to the initial guess, resulting in convergence to local minima far from the true solution. We propose a method of accelerating and stabilizing FADS application to sequences of dynamic PET images by adding preliminary cluster analysis of the time activity curves for individual voxels. We treat the temporal variation of individual voxel concentrations as a set of time-series and use a partial clustering analysis to identify the types of voxel TACs that are most functionally distinct from each other. These TACs provide a good initial guess for the temporal factors for subsequent FADS processing. Applying this approach to a set of single slices of dynamic 11C-PIB images of the brain allows identification of the arterial input function and two different tissue TACs that are likely to correspond to the specific and non-specific tracer binding-tissue types. These results enable application of standard kinetic parameter analysis methods such as Logan plots used in dynamic PET without relying on identification of the reference

region or without using any external methods of estimating the arterial input function.

9417-36, Session 8

Very low-dose adult whole-body tumor imaging with F-18 FDG PET/CT

Andrzej Krol, Muhammad A. Naveed, Mary A. McGrath, Michele Lisi, Cathy Lavalley, David H. Feiglin, SUNY Upstate Medical Univ. (United States)

The aim of this study was to evaluate if the radiation dose due to PET component in adult whole-body tumor imaging with F-18 FDG PET/CT could be significantly reduced using recently introduced PET with LYSO detector and time-of-flight (FX) technique, and SharpIR (SIR) algorithm.

In previous studies, we have established that whole-body tumor imaging with F-18 FDG PET/CT using D690 (GE) scanner with LYSO detector using FX and SIR algorithm, following the administration of 5 mCi of F-18 FDG, i.e. the half of the lowest amount of FDG administered activity recommended by ACR, produces good diagnostic quality PET images. In our protocol, the whole-body PET images were obtained in 3-minute per bed position scans. In order to further reduce the radiation dose to patients, we simulated additional 33% F-18 FDG dose reduction (to 3.3 mCi) via reconstruction of simulated 2-minute per bed position scans from the acquired list data. F-18 FDG whole-body scans were reconstructed using VUE Point with FX and SIR algorithm. We used 2.0 mm Gaussian in-plane post filter, heavy axial filter and 18/4 and 16/8 subsets/iterations for 5 mCi and 3.3 mCi dose, respectively. Two groups of images were obtained: group A with 5 mCi dose and group B with 3.3 mCi dose, respectively. Four nuclear medicine physicians blinded to the administered activity independently reviewed the images and compared diagnostic quality of images.

All the lesions observed in the group A were visible in the group B. The tumor SUV values were different in the group A, as compared to group B, respectively. No significant differences were reported in the final interpretation of the images from A and B groups.

This study indicates that the radiation dose from F-18 FDG PET for our 10 adult patients in whole-body PET/CT studies could be reduced by administration of 3.3 mCi instead of 5 mCi without compromising the diagnostic performance. In order to compare SUV in lateral studies the same protocols need to be applied in all scans. The larger clinical trials are needed to confirm that the additional 33% dose reduction could be applied to all adult patients.

9417-37, Session 8

Improved characterization of molecular phenotypes in breast lesions using 18F-FDG PET image homogeneity

Kunlin Cao, Roshni Bhagalia, Anup Sood, GE Global Research (United States); Edi Brogi, Ingo K. Mellinghoff, Steven M. Larson, Memorial Sloan-Kettering Cancer Ctr. (United States)

Positron emission tomography (PET) using fluorodeoxyglucose (18F-FDG) is commonly used in the assessment of breast lesions by computing voxel-wise standardized uptake value (SUV) maps. Simple metrics derived from ensemble properties of SUVs within each identified breast lesion are routinely used for disease diagnosis. The maximum SUV within the lesion (SUVmax) is the most popular of these metrics. However these simple metrics are known to be error-prone and are susceptible to image noise. Finding reliable SUV map-based features that correlate to established molecular phenotypes of breast cancer (viz. estrogen receptor (ER), progesterone receptor (PR) and human epidermal growth factor receptor 2 (HER2) expression) will enable non-invasive disease management. This study investigated 36 SUV features based on first and second order

statistics, local histograms and texture of segmented lesions to predict ER and PR expression in 51 breast cancer patients. True ER and PR expression was obtained via immunohistochemistry (IHC) of tissue samples from each lesion. A supervised learning, adaptive boosting-support vector machine (AdaBoost-SVM), framework was used to select a subset of features to classify breast lesions into distinct phenotypes. Performance of the trained multi-feature classifier was compared against the baseline single-feature SUVmax classifier using receiver operating characteristic (ROC) curves. Results show that texture features encoding local lesion homogeneity extracted from gray-level co-occurrence matrices are the strongest discriminator of lesion ER expression. In particular, classifiers including these features increased prediction accuracy from 0.75 (baseline) to 0.82 and the area under the ROC curve from 0.64 (baseline) to 0.75.

9417-39, Session 8

MRI assessment of changes in tumor oxygenation post hypoxia-targeted therapy

Shubhangi Agarwal, Rohini Vidya Shankar, Arizona State Univ. (United States); Landon J. Inge, St. Joseph's Hospital and Medical Ctr. (United States); Vikram D. Kodibagkar, Arizona State Univ. (United States)

Tissue hypoxia is a prevalent physiological condition in various pathologies such as cancer, ischemic heart disease and stroke. In the tumor microenvironment, the combination of compromised oxygen supply and high demand results in formation of regions of acute and chronic hypoxia which promotes metastasis, proliferation, resistance to chemo and radiotherapy and poor prognosis. Targeted, non-invasive in vivo imaging of hypoxia has the potential to determine regions with poor oxygenation in the target and differentiate between normoxic vs hypoxic tissues. MRI provides a powerful platform for generating quantitative maps of hypoxia with the use of a novel pO2 measuring technique PISTOL (Proton imaging of siloxanes to map tissue oxygenation levels) which could impact the therapeutic choices. In the present study, PISTOL was used to determine the changes in oxygenation of tumor in pre-clinical models of NSCLC and epidermoid carcinoma in response to tirapzamine (TPZ), a hypoxia activated therapeutic intervention. The tumor volume data indicates that tirapazamine was effective in slowing the tumor growth in NSCLC as compared to epidermoid carcinomas. Significantly lower baseline pO2 was observed in epidermoid carcinomas as compared to NSCLC tumors.

9417-40, Session 8

Evaluation of A Targeted Nanobubble Ultrasound Contrast Agent for Potential Tumor Imaging

Chunfang Li, Chunxu Shen, Haijuan Liu, Kaizhi Wu, Qibing Zhou, Mingyue Ding, Huazhong Univ. of Science and Technology (China)

Targeted nanobubbles (TNBs) have been reported to improve the contrast effect of ultrasound imaging due to the enhanced permeation and retention effects at tumor vascular leaks. In this work, the contrast enhancement abilities and the tumor-targeted potential of a self-made nanobubble ultrasound contrast agent was evaluated in vitro and in vivo. Size distribution and zeta potential were assessed. Then the contrast-enhanced ultrasound imaging of the TNBs was evaluated with a custom-made experimental apparatus and in normal Wistar rats. Finally, the in vivo tumor-targeting ability was evaluated on nude mice with subcutaneous tumor. The results showed that the target nanobubbles had uniform distribution with the average diameter of 142.4 nm, polydispersity index (PDI) of 0.447, and zeta potential of -23.41 mV. Significant contrast enhancement was observed in both in vitro and in vivo ultrasound imaging, demonstrating that the self-made target nanobubbles can enhance the contrast effect

of ultrasound imaging efficiently. Targeted tumor imaging showed less promising result, due to the fact that the target nanobubbles arriving and permeating through tumor vessels were not many enough to produce significant enhancement. Future work will focus on exploring new imaging algorithm which is sensitive to target nanobubbles, so as to correctly detect the contrast agent, in particular at low concentrations of the agent.

9417-104, Session 8

A pilot study of the prognostic significance of metabolic tumor size measurements in PET/CT imaging of lymphomas

Maria Kallergi, Maria Botsivali, Nikolaos Politis, Dimitrios Menychtas, Technological Educational Institute of Athens (Greece); Alexandros Georgakopoulos, Biomedical Research Foundation, Academy of Athens (Greece); Sofia Chatziioannou, National and Kapodistrian Univ. of Athens (Greece)

PURPOSE: This study explores changes in metabolic tumor diameter and volume with treatment and relationships to changes in maximum SUV (SUVmax) for earlier identification of lymphomas' response to treatment.

MATERIAL & METHODS: Pre- and post-treatment FDG-PET/CT studies of 20 patients with Hodgkin disease (HL) and 20 patients with non-Hodgkin lymphoma (NHL) were retrospectively selected for this study. The diameter and volume of the metabolic tumor was determined by an in-house developed semi-automatic technique based on a percentage threshold (50%) of the maximum pixel value. The maximum anatomic diameter was determined by an expert from the CT scan. Statistical analysis aimed at the identification of associations between anatomical and metabolic size measurements and between size measurements and SUVmax.

RESULTS: Analysis of the data is ongoing. The results from 10 HL and NHL patients, who showed improvement with treatment, led to linear correlations (R=0.34) between the anatomical diameter and SUVmax, weaker correlations (R=0.30) between the metabolic diameter and SUVmax and a stronger correlation (R=0.45) between the metabolic volume and SUVmax. Metabolic tumor volume changes show a stronger association with SUVmax changes (R=0.68) than metabolic diameter or anatomical diameter changes.

CONCLUSIONS: Preliminary results on lymphoma patients that responded to treatment suggest that metabolic tumor volume could have a major prognostic value. However, metabolic volume measurements of lymphomas depend highly on the segmentation methodology, in agreement with prior reports on gastrointestinal cancer, and a standardized, reproducible approach is necessary. Final results of this study will be reported in the manuscript and the conference.

9417-110, Session 8

Fluorescence imaging to study cancer burden on lymph nodes

Alisha V. DSouza, Jonathan T. Elliott, Jason R. Gunn, Thayer School of Engineering at Dartmouth (United States); Kimberley S. Samkoe, Geisel School of Medicine (United States); Kenneth M. Tichauer, Illinois Institute of Technology (United States); Brian W. Pogue, Thayer School of Engineering at Dartmouth (United States)

Morbidity and complexity involved in lymph node staging via surgical resection and biopsy calls for staging techniques that are less invasive. While visible blue dyes are commonly used in locating sentinel lymph nodes, since they follow tumor-draining lymphatic vessels, they do not provide a metric to evaluate presence of cancer. An area of active research is to use fluorescent dyes to assess tumor burden of sentinel and secondary lymph nodes.

The goal of this work was to successfully use fluorescence properties of a clinically relevant blue dye, specifically methylene blue - used in the sentinel lymph node procedure – to quantitatively segregate tumor bearing from normal lymph nodes, using planar fluorescence imaging. A direct-injection based tumor model was employed in athymic rats (6 control, 5 tumor-bearing), where luciferase-expressing breast cancer cells were injected into axillary lymph nodes. Tumor presence in nodes was confirmed by bioluminescence imaging before and after fluorescence imaging. Lymphatic uptake from the injection site (intradermal on forepaw) to lymph node was imaged at approximately 2 frames/minute. Large variability was observed within each cohort, resulting in no observable difference between average nodal uptake in normal and tumor-bearing nodes; however, when lymph vessel input fluorescence was used to account for heterogeneities in nodal uptake, heterogeneity in nodal fluorescence resulting from differences in delivery could be corrected. Following this correction, a significant difference (p<0.05) was observed between normal and tumor-bearing nodes owing to the differences in lymph system flow rate, owing to tumor cell disruption of flow through the nodes.

9417-41, Session 9

Principal component analysis of the CT density histogram to generate parametric response maps of COPD

Nanxi Zha, Dante P. I. Capaldi, Damien Pike, David G. McCormack, Ian A. Cunningham, Grace Parraga, The Univ. of Western Ontario (Canada)

Purpose: Computed tomography (CT) imaging of the lung can be used to characterize the heterogeneity of chronic obstructive pulmonary disease (COPD). In this study, we compare COPD phenotypes calculated from parametric response mapping (PRM) using principal component analysis (PCA) of the CT density histogram against known markers of COPD.

Methods: PRM was previously developed by setting tissue thresholds (Hounsfield Units) on registered inspiratory and expiratory CT to differentiate emphysema, small airways disease, and healthy lung parenchyma. These attenuation thresholds do not necessarily reflect characteristics in the individual subject. Here, we modified this approach by first employing PCA on the CT density histograms. This generated a set of attenuation thresholds more specific to the subject being evaluated to create a PCA-adjusted PRM for COPD phenotypes.

Results: In nine ex-smokers with Global Initiative for Chronic Obstructive Lung Disease (GOLD) grades I-III, regions of small airways disease and emphysema calculated from PCA-adjusted PRM was compared with well-defined COPD measurements and significant correlation (p < 0.05) was observed for apparent diffusion coefficient, a measurement of emphysema.

Conclusions: Through correlations observed against well-defined COPD measurements, thresholds generated from PCA show promise to better PRM as a measurement of COPD phenotypes.

9417-42, Session 9

Automated pulmonary lobar ventilation measurements using volume-matched thoracic CT and MRI

Fumin Guo, Sarah Svenningsen, Emma Bluemke, Martin Rajchl, Jing Yuna, Aaron Fenster, Grace Parraga, Robarts Research Institute (Canada)

Objectives: To develop and evaluate an automated registration and segmentation pipeline for regional lobar pulmonary structure-function maps, using volume-matched thoracic CT and MRI in order to guide therapy.

Methods: Ten subjects underwent pulmonary function tests and volume-matched 1H and 3He MRI and thoracic CT during a single 2 hr visit. CT was

registered to 1H MRI using an affine method that incorporated block-matching and this was followed by free-form deformation. The resultant deformation field was used to deform the associated CT lobe mask that was generated using commercial software. 3He-1H image registration used the same two-step registration method and 3He ventilation was segmented using hierarchical k-means. Whole lung and lobar 3He ventilation and ventilation defect percent (VDP) were generated by mapping ventilation defects to CT-defined whole lung and lobe volumes. Registration accuracy was evaluated using region-, distance- and volume- based metrics. Automated whole lung and lobar VDP was compared with semi-automated and manual results using analysis of variance.

Results: The proposed pipeline yielded regional spatial agreement of 88.00.9% and distance error of 3.90.5 mm. Automated and manual whole lung and lobar ventilation and ventilation defect percent were not significantly different and they were significantly correlated (r = 0.77, p < 0.0001).

Conclusion: The proposed automated pipeline can be used to generate regional pulmonary structural-functional maps with high accuracy and robustness, providing an important tool for image-guided pulmonary interventions.

9417-43, Session 9

3D cine magnetic resonance imaging of rat lung ARDS using gradient-modulated SWIFT with retrospective respiratory gating

Naoharu Kobayashi, Jianxun Lei, Lynn Utecht, Univ. of Minnesota (United States); Michael Garwood, Univ. of Minnesota, Twin Cities (United States); David Ingbar, Maneesh Bhargava, Univ. of Minnesota (United States)

SWeep Imaging with Fourier Transformation (SWIFT) with gradient modulation and DC navigator retrospective gating is introduced as a 3D cine magnetic resonance imaging (MRI) method for the lung. The quasi-simultaneous excitation and acquisition in SWIFT enabled extremely high sensitivity to the fast-decaying parenchymal signals (TE=~4 ?s), which are invisible with conventional MRI techniques. Based on respiratory motion information extracted from DC navigator signals, the SWIFT data were reconstructed to 3D cine images with 16 respiratory phases. To test the capability of the proposed technique, rats exposed to > 95% O2 for 60 hours for induction of acute respiratory distress syndrome (ARDS), were imaged and compared with normal rat lungs (N=3 in each group). In the cine SWIFT images, parenchymal signal drop at the inhalation phase was consistently observed for both normal and ARDS rats due to inflation of the lung (i.e decrease of the proton density), but the drop was less for ARDS rats. The lungs from the ARDS rats showed 3-27% higher parenchymal signal intensities relative to the normal rat lungs, which would be mainly from accumulation of extravascular water (EVLW). Volumetric analyses for the SWIFT images revealed lower tidal volume (Tv) and higher functional residual capacity (FRC) for the ARDS rats (Tv=1.28±0.13 and 0.97±0.03 ml and FRC=3.14±0.14 and 3.59±0.15 ml for normal and ARDS rats, respectively). Those results demonstrate that SWIFT has high enough sensitivity for detecting the lung proton density changes due to different respiration phases and accumulation of EVLW in the ARDS rats.

9417-44, Session 9

Texture analysis of automatic graph cuts segmentations for detection of lung cancer recurrence after stereotactic radiotherapy

Sarah A. Mattonen, The Univ. of Western Ontario (Canada); David A. Palma, The Univ. of Western Ontario (Canada)

and London Regional Cancer Program (Canada); Cornelis J. A. Haasbeek, Suresh Senan, Vrije Univ. Medical Ctr. (Netherlands); Aaron D. Ward, The Univ. of Western Ontario (Canada)

Stereotactic ablative radiotherapy (SABR) is a treatment for early-stage lung cancer with local control rates comparable to surgery. After SABR, benign radiation induced lung injury (RILI) results in tumour-mimicking changes on computed tomography (CT) imaging. Distinguishing recurrence from RILI is a critical clinical decision determining the need for potentially life-saving salvage therapies whose high risks in this population dictate their use only for true recurrences. Current approaches do not reliably detect recurrence within a year post-SABR. We measured the detection accuracy of texture features within automatically determined regions of interest, with the only operator input being the single line segment measuring tumour diameter, normally taken during the clinical workflow. Our leave-one-out cross validation on images taken 2–5 months post-SABR showed robustness of the entropy measure, with classification error of 26% and area under the receiver operating characteristic curve (AUC) of 0.77 using automatic segmentation; the results using manual segmentation were 24% and 0.75, respectively. AUCs for this feature increased to 0.82 and 0.93 at 8–14 months and 14–20 months post SABR, respectively, suggesting even better performance nearer to the date of clinical diagnosis of recurrence; thus this system could also be used to support and reinforce the physician's decision at that time. Based on our ongoing validation of this automatic approach on a larger sample, we aim to develop a computer-aided diagnosis system which will support the physician's decision to apply timely salvage therapies and prevent patients with RILI from undergoing invasive and risky procedures.

9417-45, Session 9

Fourier-based linear systems description of free-breathing pulmonary magnetic resonance imaging

Dante P. I. Capaldi, Sarah Svenningsen, Ian A. Cunningham, Grace Parraga, Robarts Research Institute (Canada)

Fourier-decomposition of free-breathing pulmonary magnetic resonance imaging (FDMRI) was recently piloted as a way to provide rapid quantitative pulmonary maps of ventilation and perfusion without the use of exogenous contrast agents. This method exploits fast pulmonary MRI acquisition of free-breathing proton (1H) pulmonary images and non-rigid registration to compensate for changes in position and shape of the thorax associated with breathing. In this way, ventilation imaging using conventional MRI systems can be undertaken but there has been no systematic evaluation of fundamental image quality measurements based on linear systems theory. Objectives: We investigated the performance of free-breathing pulmonary ventilation imaging using a Fourier-based linear system description of each operation required to generate FDMRI ventilation maps. Methods: Twelve subjects with chronic obstructive pulmonary disease (COPD) or bronchiectasis underwent pulmonary function tests and MRI. Non-rigid registration was used to co-register the temporal series of pulmonary images. Pulmonary voxel intensities were aligned along a time axis and discrete Fourier transforms were performed on the periodic signal intensity pattern to generate frequency spectra. We determined the signal-to-noise ratio (SNR) of the FDMRI ventilation maps using a conventional approach (SNRC) and using the Fourier-based description (SNRF). Results: Mean SNR was 4.7 ± 1.3 for subjects with bronchiectasis and 3.4 ± 1.8, for COPD subjects (p>.05). SNRF was significantly different than SNRC (p<.01). Conclusion: SNRF was approximately 50% of SNRC suggesting that the linear system model well-estimates the current approach.

9417-46, Session 10

Validation of CBCT for the computation of textural biomarkers

Beatriz Paniagua, The Univ. of North Carolina at Chapel Hill (United States); Antonio C. Ruellas, Erika Benavides, Univ. of Michigan School of Dentistry (United States); Steve Marron, The Univ. of North Carolina at Chapel Hill (United States); Larry Wolford, Baylor Univ. (United States); Lucia Cevidanes, Univ. of Michigan School of Dentistry (United States)

Osteoarthritis (OA) is associated with significant pain and 42.6% of patients with TMJ disorders present with evidence of TMJ OA. However, OA diagnosis and treatment remain controversial, since there are no clear symptoms of the disease. The subchondral bone in the TMJ is believed to play a major role in the progression of OA. We hypothesize that the textural imaging biomarkers computed in high resolution Conebeam CT (hr-CBCT) and μCT scans are comparable. The purpose of this study is to test the feasibility of computing textural imaging biomarkers in-vivo using hr-CBCT, compared to those computed in μCT scans as our Gold Standard. Specimens of condylar bones obtained from condylectomies were scanned using μCT and hr-CBCT. Nine different textural imaging biomarkers (four co-occurrence features and five run-length features) from each pair of μCT and hr-CBCT were computed and compared. Pearson correlation coefficients were computed to compare textural biomarkers values of μCT and hr-CBCT. Four of the nine computed textural biomarkers showed a strong positive correlation between biomarkers computed in μCT and hr-CBCT. Higher correlations in Energy and Contrast, and in GLN (grey-level non-uniformity) and RLN (run length non-uniformity) indicate quantitative texture features can be computed reliably in hr-CBCT, when compared with μCT. The textural imaging biomarkers computed in-vivo hr-CBCT have the ability to capture the structure, patterns, contrast between neighboring regions and uniformity of healthy and/or pathologic subchondral bone. The ability to quantify bone texture non-invasively now makes it possible to evaluate the progression of subchondral bone alterations, in TMJ OA.

9417-47, Session 10

Validation of TMJ Osteoarthritis synthetic defect database created using non-rigid registration

Beatriz Paniagua, Juliette Pera, Francois Budin, The Univ. of North Carolina at Chapel Hill (United States); Liliane Rosas Gomes D.D.S., University of Michigan, School of Dentistry (United States); Martin Styner, The Univ. of North Carolina at Chapel Hill (United States); Lucia Helena Soares Cevidanes D.D.S., University of Michigan, School of Dentistry (United States); Tung Nguyen, The Univ. of North Carolina at Chapel Hill (United States)

Temporomandibular joint (TMJ) disorders are a group of conditions that cause pain and dysfunction in the jaw joint and the muscles controlling jaw movement. However, diagnosis and treatment of these conditions remain controversial. To date, there is no single sign, symptom, or test that can clearly diagnose early stages of osteoarthritis (OA). Instead, the diagnosis is based on a consideration of several factors, including radiological evaluation. The current radiological diagnosis scores of TMJ pathology are subject to misdiagnosis. We believe these scores are limited by the acquisition procedures, such as oblique cuts of the CT and head positioning errors, and can lead to incorrect diagnoses of flattening of the head of the condyle, formation of osteophytes, or condylar pitting. This study consists of creating and validating a methodological framework to simulate defects in CBCT scans of known location and size, in order to create synthetic TMJ OA database. User-generated defects were created using a non-rigid

deformation protocol in CBCT, and evaluated. All segmentation evaluation, surface distances and linear distances from the user-generated to the simulated defects showed our methodological framework to be very precise and within a voxel (0.5 mm) of magnitude. A TMJ OA synthetic database will be created next, and evaluated by expert radiologists, and this will serve to evaluate how sensitive the current radiological diagnosis tools are.

9417-48, Session 10

Micro-computed tomography (CT) based assessment of dental regenerative therapy in the canine mandible model

Parag Khobragade, Toshiba Stroke and Vascular Research Ctr. (United States); Amit Jain, Toshiba Stroke Research Ctr. (United States); Swetadri Vasan Setlur Nagesh, Toshiba Stroke and Vascular Research Ctr. (United States); Sebastiano Andreana, Rosemary Dziak, Univ. at Buffalo (United States); Daniel R. Bednarek, Stephen Rudin, Ciprian N. Ionita, Toshiba Stroke and Vascular Research Ctr. (United States); Sasi Sunkara, Sujatha Sunkara, Department of Oral Biology (United States)

: High-resolution 3D bone-tissue structure measurements may provide information critical to the understanding of bone regeneration processes and to bone strength assessment. Tissue engineering studies rely on such measurements to monitor nondestructively, spatially resolved bone graft regeneration area. High resolution micro-CT is a powerful device for quantitative and qualitative analysis of bone structure. In this study, we measured Bone Volume Fraction (BVF) through CT slices for different grafts and controls. Eight canines underwent surgery to remove a bone volume (defect) at various locations (n=12) in the canine's jaw. We kept (n=3) defects empty for control and filled the remaining ones with two regenerative materials; NanoGen (NG), an FDA-approved material (n=4), and a novel NanoCalcium Sulfate (NCS) material (n=5). After a minimum of four weeks, the canines were sacrificed and the jaw samples were extracted. We used a custom-build micro-CT system to acquire the volume data and developed software to measure the BVFs in all the defects. The software used a segmentation algorithm based on histograms derived from volumes of interest indicated by the operator. Average BVF values were: 26.1±6 for control, 48±5.4 for NG and 73.8±13.6 for NGS. Regenerative materials showed 75% BVF improvement over controls while average BVFs for NCS were 53% (p<0.05) higher than NG controls. This study presents one of the first quantitative comparisons using non-destructive micro-CT analysis for bone regenerative materials in a large animal model. Our results indicate that micro-CT measurements can be used to monitor in-vivo bone regenerative studies for greater regenerative process understanding.

9417-49, Session 10

Characterizing trabecular bone structure for assessing vertebral fracture risk on volumetric quantitative computed tomography

Mahesh B. Nagarajan, Univ. of Rochester Medical Ctr. (United States); Walter A Checefsky, Univ of Rochester Medical Ctr (United States); Anas Z Abidin, Univ of Rochester Medical Ctr (United States); Halley Tsai, Univ. of Rochester Medical Ctr. (United States); Xixi Wang, Univ. of Rochester Medical Ctr. (United States); Susan K. Hobbs, Univ. of Rochester (United States); Jan S. Bauer, Thomas H. Baum, Technische Univ. München (Germany); Axel Wismüller, Univ. of Rochester Medical Ctr. (United States)

While the proximal femur is preferred for measuring bone mineral density (BMD) in fracture risk estimation, the introduction of volumetric quantitative computed tomography has revealed stronger associations between BMD and spinal fracture status. In this study, we propose to capture properties of trabecular bone structure in spinal vertebrae with advanced second-order statistical features for purposes of fracture risk assessment. For this purpose, axial multi-detector CT (MDCT) images were acquired from 28 spinal vertebrae specimens using a whole-body 256-row CT scanner with a dedicated calibration phantom. A semi-automated method was used to annotate the trabecular compartment in the central vertebral slice with a circular region of interest (ROI) to exclude cortical bone; pixels within were converted to values indicative of BMD. Six second-order statistical features derived from gray-level co-occurrence matrices (GLCM) and the mean BMD within the ROI were then extracted and used in conjunction with a generalized radial basis functions (GRBF) neural network to predict the failure load of the specimens; true failure load was measured through biomechanical testing. Prediction performance was evaluated with a root-mean-square error (RMSE) metric. The best prediction performance was observed with GLCM feature correlation (RMSE = 1.02 ± 0.18) which significantly outperformed all other GLCM features (p < 0.01). GLCM feature correlation also significantly outperformed MDCT-measured mean BMD (RMSE = 1.11 ± 0.17) (p < 10-4). These results suggest that biomechanical strength prediction in spinal vertebrae can be significantly improved through characterization of trabecular bone structure with GLCM-derived texture features.

9417-50, Session 10

Volumetric characterization of human patellar cartilage matrix on phase contrast x-ray computed tomography

Anas Z. Abidin, Mahesh B. Nagarajan, Univ. of Rochester Medical Ctr. (United States); Paola Coan, Paul C. Diemoz, Ludwig-Maximilians-Univ. München (Germany); Walter A Checefsky, Univ of Rochester Medical Ctr (United States); Susan K. Hobbs, Markus B. Huber, Axel Wismueller, Univ. of Rochester Medical Ctr. (United States)

Phase contrast X-ray computed tomography (PCI-CT) has recently emerged as a novel imaging technique that allows visualization of cartilage soft tissue, subsequent examination of chondrocyte patterns, and their correlation to osteoarthritis. Previous studies have shown that 2D texture features are effective at distinguishing between healthy and osteoarthritic regions of interest annotated in the radial zone of cartilage matrix on PCI-CT images. In this study, we further extend the texture analysis to 3D and investigate the ability of volumetric texture features at characterizing chondrocyte patterns in the cartilage matrix for purposes of classification. Here, we extracted volumetric texture features derived from Minkowski Functionals and gray-level co-occurrence matrices (GLCM) from 496 volumes of interest (VOI) annotated on PCI-CT images of human patellar cartilage specimens. The extracted features were then used in a machine learning task involving support vector regression to classify ROIs as healthy or osteoarthritic. Classification performance was evaluated using the area under the receiver operating characteristic (ROC) curve (AUC). The best classification performance was observed with GLCM features correlation (AUC = 0.83 ± 0.06) and homogeneity (AUC = 0.82 ± 0.07), which significantly outperformed all Minkowski Functionals (p < 0.05). These results suggest that such quantitative analysis of chondrocyte patterns in human patellar cartilage matrix involving GLCM-derived geometrical features can distinguish between healthy and osteoarthritic tissue with high accuracy.

9417-51, Session 10

Real time early detection system of failed wounds and heterotopic ossification imaging system using unique Raman signatures

Asael Papour, Zachary D. Taylor, Oscar M. Stafsudd, Warren S. Grundfest, Univ. of California, Los Angeles (United States)

Raman emission, specifically Stokes scattering, is process in which a molecule absorbs an incoming photon and relaxes to a different vibrational (or rotational) state by emission of a longer wavelength photon. The difference in energy between the two ground states is the source of the wavelength difference and is called a Raman shift. This shift spectra is used to identify molecules and substances with extreme accuracy and serves as a material's fingerprint.

Raman imaging system entails a scheme to detect Phosphate (P=O) Raman shift (959cm-1), a highly detectable vibrational state of a chemical bond in hydroxyapatite (Ca10(PO4)6(OH)2) which is the key inorganic constituent of the bone matrix and commonly found in failed wounds suffering from heterotopic ossification. The strategy that is explored uses near-infrared continuous wave excitation at 785nm and Raman detection that utilizes two distinct wavelengths at 852 and 849 nm to create a final image. This method enables relative Raman measurement by eliminating fluorescence background while remaining sensitive to the Raman signatures of the bone.

The chosen approach focuses on a single bandwidth capturing a unique Raman peak, enables fast detection with simple components and results in a cost effective system that can be employed in a clinical setting with the ability to tune different detection bands and adjust to various medical applications. Moreover, the Raman imaging technology can be extended and used in non-medical application where contrast generation is paramount.

9417-52, Session PSWed

Simplified correction of B1 inhomogeneity for chemical exchange saturation transfer (CEST) MRI measurement with surface transceiver coil

Phillip Z. Sun, Massachusetts General Hospital and Harvard Medical (United States) and Harvard Univ. School of Medicine (United States); Iris Y. Zhou, Takahiro Igarashi, Yingkun Guo, Massachusetts General Hospital (United States); Gang Xiao, Hanshan Normal Univ. (China); Renhua Wu, Shantou Univ. Medical College (China)

Chemical exchange saturation transfer (CEST) MRI is sensitive to dilute exchangeable protons and local properties such as pH and temperate, yet its susceptibility to field inhomogeneity limits its in vivo applications. Particularly, CEST measurement varies with RF irradiation power, the dependence of which is complex due to concomitant direct RF saturation (RF spillover) effect. Because the volume transmitters provide relatively homogeneous RF field, they have been conventionally used for CEST imaging despite of their elevated specific absorption rate (SAR) and relatively low sensitivity than surface coils. To address this limitation, we developed an efficient B1 inhomogeneity correction algorithm that enables CEST MRI using surface transceiver coils. This is built on recent work that showed the inverse CEST asymmetry analysis (CESTRind) is not susceptible to confounding RF spillover effect. We here postulated that the linear relationship between RF power level and CESTRind can be extended for correcting B1 inhomogeneity induced CEST MRI artifacts. Briefly, we prepared a tissue-like Creatine gel pH phantom and collected multi-parametric MRI including relaxation, field map and CEST MRI under multiple RF power levels, using a conventional surface transceiver coil. The raw CEST images showed substantial heterogeneity due to B1 inhomogeneity, with pH

contrast to noise ratio (CNR) being 8.8. In comparison, pH MRI CNR of the field-inhomogeneity corrected CEST MRI was found to be 17.2, substantially higher than that without correction. To summarize, our study validated an efficient field inhomogeneity correction that enables sensitive CEST MRI with surface transceiver, promising for in vivo translation.

9417-53, Session PSWed

Imaging tooth enamel using Zero Echo Time (ZTE) MRI

Barjor Gimi, Dartmouth Hitchcock Medical Ctr. (United States); Gang Zhu, Bruker BioSpin Corp. (United States); Kevin Rychert, Venkata K. Nemani, Benjamin Williams, Ann B. Flood, Harold M. Swartz, Dartmouth College (United States)

To effectively manage medical care following radiation events causing potential mass exposure, new technology is needed to retrospectively provide individual absorbed dose estimates. Radiation exposure generates persistent free radicals in mineralized tissue such as tooth enamel, which can be queried with in vivo electron paramagnetic resonance (EPR) biodosimetry. Since dose estimates may vary depending on the amount of enamel, it is important to understand the relationship between enamel volume and dose estimates, and to understand how to practically assess enamel volume in a disaster situation. The first step is to understand the fundamental relationship between dose estimates and enamel thickness or its spatial distribution within the detector or other structural sources of tooth-specific variations. MRI can assess these variables by imaging the structure, without imparting additional radiation that would confound the aforementioned radiation dose estimate.

We used zero echo time (ZTE) MRI to image tooth enamel and identify structural anomalies that may be a potential source of aberrant EPR signals. ZTE MRI effectively quantitates enamel volume and is comparable to microCT. In 67 teeth, enamel volume correlated weakly with EPR estimates of background radiation signals. Importantly, ZTE MRI revealed dental caries and other anomalies not easily identified by visual inspection but which can effect EPR signals. In one tooth with no known radiation exposure or physical abnormalities but having an unusually high EPR signal, a large susceptibility signature was observed using MRI. Our findings encourage further exploration of the application of ZTE MRI to sources of aberrant/high EPR signal.

9417-54, Session PSWed

Rapid MR spectroscopic imaging of lactate using compressed sensing

Rohini Vidya Shankar, Shubhangi Agarwal, Arizona State Univ. (United States); Sairam Geethanath, Dayanand Sagar College of Engineering (India); Vikram D. Kodibagkar, Arizona State Univ. (United States)

Purpose: Imaging lactate metabolism in vivo may improve cancer targeting and therapeutics due to its key role in the development, maintenance, and metastasis of cancer. The long acquisition times associated with magnetic resonance spectroscopic imaging (MRSI), which is a useful technique for assessing metabolic concentrations, are a deterrent to its routine clinical use. The objective of this study was to combine spectral editing and prospective compressed sensing (CS) acquisitions to enable precise and high-speed imaging of the lactate resonance.

Methods: A MRSI pulse sequence with two key modifications was developed: (1) Spectral editing components for lactate, and (2) A variable density sampling mask for pseudo-random undersampling of the k-space 'on the fly'. The developed sequence was tested on phantoms and in vivo in rodent models of cancer. Datasets corresponding to the 1X (fully-sampled), 2X, 3X, 4X, 5X, and 10X accelerations were acquired. The undersampled

datasets were reconstructed using a custom-built algorithm in MatlabTM, and the fidelity of the CS reconstructions was assessed in terms of the peak amplitudes, SNR, and total acquisition time.

Results: The accelerated reconstructions demonstrate a reduction in the scan time by up to 90%, in vitro and up to 80% in vivo, with negligible loss of information when compared with the 1X reference dataset.

Conclusion: The proposed unique combination of spectral editing and CS facilitated rapid mapping of the spatial distribution of lactate at high temporal resolution. This technique could potentially be translated to the clinic for the routine assessment of lactate changes in solid tumors.

9417-55, Session PSWed

A Laplacian-based SNR measure: shear stiffness estimation in MR elastography

Rehman S. Eon, Viterbo Univ. (United States); Khang T. Huynh, The Univ. of Texas at Austin (United States); David S. Lake, Armando Manduca, Mayo Clinic (United States)

Magnetic Resonance Elastography (MRE) is a phase-contrast MRI based technique that allows quantitative, noninvasive assessment of the mechanical properties of tissues by the introduction of shear waves into the body and measurement of the resulting displacements. In MRE, the calculated stiffness values are affected by noise, which is amplified by the inversion process. It is beneficial to have an ideal SNR threshold for which the stiffness calculations can be trusted. Several methods have been developed to calculate SNR values in MRE. The most common method is a motion-based SNR measure, which estimates the noise in the measured displacement. More recently, the SNR of the octahedral shear strain (OSS) has been proposed as a more appropriate measure, since shear deformation is the signal in MRE. We also here propose a measure based on the SNR of the Laplacian of the data, since this is the quantity calculated when performing direct inversion of the Helmholtz equation. The three SNR measurements were validated on simulated data at three different wavelengths with varying amounts of noise. The stiffness was calculated for this simulated data using three inversion algorithms commonly used in MRE (phase gradient, local frequency estimation, and direct inversion). Analysis of the data shows that for stiffness calculations done using local frequency estimation and phase gradient, SNR estimation based on OSS provides a reliable measure for the calculation. However, for the direct inversion algorithm, the Laplacian SNR seems to be the best measure.

9417-56, Session PSWed

Interaction of multiple networks modulated by the working memory training based on real-time fMRI

Jiahui Shen, Li Yao, Xiaojie Zhao, Beijing Normal Univ. (China)

Neuroimaging studies of working memory training have identified the alteration of brain activity as well as the regional interactions within the functional networks such as central executive network (CEN) and default mode network (DMN). However, how the interaction within and between these multiple networks is modulated by the training remains unclear. In this paper, we examined the interaction of three training-induced brain networks during working memory training based on real-time functional magnetic resonance imaging (rtfMRI). Thirty subjects assigned to the experimental and control group respectively participated in two times training separated by seven days. Three networks including silence network (SN), CEN and DMN were identified by the training data with the calculated function connections within each network. Structural equation modeling (SEM) approach was used to construct the directional connectivity patterns. The results showed that the causal influences from the percent signal changes of target ROI to the SN were positively increased in both two groups, as well as the causal influence from the SN to CEN was positively changed in

experimental group but negatively changed in control group from the SN to DMN. Further correlation analysis of the changes in each network with the behavioral improvements showed that the changes in SN were stronger positively correlated with the behavioral improvement of letter memory task. These findings indicated that the SN was not only a switch between the target ROI and the other networks in the feedback training but also an essential factor to the behavioral improvement.

9417-57, Session PSWed

Functional connectivity analysis in resting state fMRI with echo-state networks and non-metric clustering for network structure recovery

Axel Wismüller, Adora M. D'Souza, Univ. of Rochester Medical Ctr. (United States); Anas Z Abidin, Univ of Rochester Medical Ctr (United States); Xixi Wang, Susan K. Hobbs, Mahesh B. Nagarajan, Univ. of Rochester Medical Ctr. (United States)

Echo state networks (ESN) are recurrent neural networks where the hidden layer is replaced with fixed reservoir of neurons. Unlike feed-forward networks, neuron training in ESN is restricted to the output neurons alone thereby providing a computational advantage. We demonstrate the use of such ESNs in our mutual connectivity analysis (MCA) framework for recovering the primary motor cortex network associated with hand movement from resting state functional MRI (fMRI) data. Such a framework consists of two steps - (1) defining a pair-wise affinity matrix between different pixel time series within the brain to characterize network activity and (2) recovering network components from the affinity matrix with non-metric clustering. Here, ESNs are used to evaluate pair-wise cross-estimation performance between pixel time series to create the affinity matrix, which is subsequently subject to non-metric clustering with the Louvain method. For comparison, the ground truth of the motor cortex network structure is established with a task-based fMRI sequence. Overlap between the primary motor cortex network recovered with our model free MCA approach and the ground truth was measured with the Dice coefficient. Our results show that network recovery with our proposed MCA approach is in close agreement with the ground truth. Such network recovery is achieved without requiring low-pass filtering of the time series ensembles prior to analysis, an fMRI pre-processing step that has courted controversy in recent years. Thus, we conclude our MCA framework can allow recovery and visualization of the underlying regional network in the brain on resting state fMRI.

9417-58, Session PSWed

Combining mutual information and non-metric clustering for functional connectivity analysis in resting-state functional MRI

Xixi Wang, Mahesh B. Nagarajan, Univ. of Rochester Medical Ctr. (United States); Anas Z Abidin, Univ of Rochester Medical Ctr (United States); Adora M. D'Souza, Susan K. Hobbs, Axel Wismüller, Univ. of Rochester Medical Ctr. (United States)

Functional MRI (fMRI) is currently used to measure and/or evaluate the structural or functional connectivity in human brain networks. To this end, previous studies have proposed computational methods that assumed linear coupling of the fMRI signals or required dimension reduction, and thus induced information loss. This study presents a new computational framework for investigating the functional connectivity in the brain and recovering network structure while reducing the information loss inherent in previous methods. For this purpose, pair-wise mutual information (MI)

was extracted from all pixel time series within the brain on resting-state fMRI data. Non-metric topographic mapping of proximity (TMP) algorithm was subsequently applied to recover network structure from the pair-wise MI analysis. Our computational framework is demonstrated in the task of identifying regions of the primary motor cortex associated with hand movement on resting state fMRI data. For ground truth comparison, we also identified primary motor cortex regions in a task-based fMRI sequence with a finger-tapping stimulus function. The similarity between our pair-wise MI clustering results and the ground truth is evaluated using the dice coefficient. Our results show that non-metric clustering with the TMP algorithm, as performed on pair-wise MI analysis, was able to detect the primary motor cortex network and achieved a dice coefficient of 0.53 in terms of overlap with the ground truth. Thus, we conclude that our computational framework can extract and visualize valuable information concerning the underlying network structure and between different regions of the brain in resting state fMRI.

9417-59, Session PSWed

Decoding the subjective rotation direction of the spinning dancer from fMRI data

Sutao Song, Univ. of Jinan (China); Yang Liu, Jiacai Zhang, Beijing Normal Univ. (China)

A challenging goal in neuroscience is to decode the mental states from brain activity. Recently, researchers have successfully deciphered the objective and static visual stimuli (such as orientation of stripes and category of objects) from brain activity recorded by functional magnetic resonance imaging (fMRI) technology. However, few studies focused on the decoding of the rotation direction perception of the actual three-dimensional world with two-dimensional representations. In this study, the brain activities when subjects viewed the animation of the spinning dancer in the front were recorded using fMRI, and subjects reported the viewing-from-above motion direction (clockwise or counter-clockwise) by press different buttons. One multivariate pattern analysis method, support vector machine was trained to predict the rotation direction. The 5-fold cross-validation result showed that the subjective rotation direction reported by the subjects can be predicted from fMRI with a possibility above the chance level, which imply that fMRI activity of the brain contains detailed rotation direction information that can reliably predict the subjective perception.

9417-60, Session PSWed

Structural development of human brain white matter from mid-fetal to perinatal stage

Austin Ouyang, The Univ. of Texas Southwestern Medical Ctr. at Dallas (United States); Qiaowen Yu, The Univ. of Texas Southwestern Medical Ctr. at Dallas (United States) and Shandong Univ. (China); Virendra Mishra, Lina Chalak, Tina Jeon, Muraleedharan Sivarajan, Greg Jackson, Nancy Rollins, The Univ. of Texas Southwestern Medical Ctr. at Dallas (United States); Shuwei Liu, Shandong Univ. (China); Hao Huang, The Univ. of Texas Southwestern Medical Ctr. at Dallas (United States)

The structures of developing brain white matter (WM) tracts can be effectively quantified by DTI-derived metrics, including fractional anisotropy (FA), mean, axial and radial diffusivity (MD, AD and RD). However, dynamics of WM microstructure during very early developmental period from mid-fetal to perinatal stage is unknown. It is difficult to accurately measure microstructural properties of these WM tracts due to severe contamination from cerebrospinal fluid (CSF). In this study, high resolution DTI of fetal brains at mid-fetal stage (20 weeks of gestation or 20wg), 19 brains in the middle of 3rd trimester (35 wg) and 17 brains around term

(40wg) were acquired. We established first probabilistic DTI templates at these three time points and extracted WM skeleton. 16 major WM tracts in limbic, projection, commissural and association tract groups were traced with DTI tractography in native space. The WM skeleton in the template space was inversely transformed back to the native space for measuring core WM microstructures of each individual tract. Continuous increases of tract volumes and microstructures were found from 20wg to 40wg. The volume increase of prefrontal WM tracts is accelerated in late 3rd trimester compared to mid-fetal to middle 3rd trimester, while microstructural measurement of FA is decelerated. The microstructural enhancement is heterogeneous among different tract groups with microstructures of association and projection tracts undergoing most dramatic change. The FA increases while MD, AD and RD decreases for most major WM tracts during late 3rd trimester, indicating not only active myelination but also axonal packing process.

9417-61, Session PSWed

A non-linear regression method for CT brain perfusion analysis

Edwin Bennink, Jaap Oosterbroek, Max A. Viergever, Birgitta K. Velthuis, Hugo W. A. M. de Jong, Univ. Medical Ctr. Utrecht (Netherlands)

CT perfusion (CTP) imaging allows for rapid diagnosis of ischemic stroke. Generation of perfusion maps from CTP data usually involves deconvolution algorithms, providing estimates for the impulse response function in the tissue. We propose the use of a fast non-linear regression (NLR) method that we postulate has similar performance to the current academic state-of-art method (bSVD), but that has some important advantages, including the estimation of vascular permeability and tracer-delay, and very few tuning parameters, that are all important in stroke assessment. The aim of this study is to evaluate the fast NLR method against bSVD and a commercial clinical state-of-art method.

The three methods were tested against a published digital perfusion phantom earlier used to illustrate the superiority of bSVD. In addition, the NLR and clinical methods were also tested against bSVD on 20 clinical scans. Pearson correlation coefficients were calculated for each of the tested methods.

The fast NLR method showed the highest correlation coefficients with the ground truth in the phantom. With respect to the clinical scans, the NLR perfusion maps showed higher correlation with bSVD than the perfusion maps from the clinical method. Furthermore, the perfusion maps showed that the fast NLR estimates are most robust to tracer-delay.

In conclusion, the proposed fast NLR method provides a simpler and more flexible way of estimating perfusion parameters from CT perfusion scans, with higher correlation coefficients. This suggests that it could be a better alternative to the current clinical and academic state-of-art methods.

9417-62, Session PSWed

Early postnatal myelin content estimate of white matter via T1/T2w ratio

Kevin Lee, Marie Cherel, Francois Budin, John H. Gilmore, Kirsten N. Zaldarriaga Consing, The Univ. of North Carolina at Chapel Hill (United States); Jerod Rasmussen, Pathik D. Wadhwa, Univ. of California, Irvine (United States); Sonja Entringer, Univ. of California, Irvine (United States) and Charite Univ. Berlin (Germany); Matthew F. Glasser, Washington Univ. School of Medicine in St. Louis (United States); David C. Van Essen, Washington Univ. School of Medicine (United States); Claudia Buss, Univ. of California, Irvine (United States) and Charité Univ. Berlin (Germany); Martin A. Styner, The Univ. of North Carolina at Chapel Hill

(United States)

Purpose: To develop and evaluate a novel processing framework for the relative quantification of myelin content in cerebral white matter regions from brain MRI data via a computed ratio of T1 to T2 weighted intensity values. Data: We employed high resolution (1mm3 isotropic) T1 and T2 weighted MRI from 46 (28 male, 18 female) neonate subjects (normal controls) scanned on a Siemen Tim Trio 3T at UC Irvine. Methods: We developed a novel, yet relatively straightforward image processing framework for myelin content estimation based on earlier work by Glasser et al. We first co-register the structural MRI data to correct for motion. Then, background areas are masked out via a joint T1w and T2 foreground mask computed via Otsu thresholding. Raw T1w/T2w-ratios images, which are largely corrected for intensity inhomogeneity, are computed next. For purpose of calibration across subjects, we first coarsely segment the fat-rich facial regions via atlas co-registration. Linear intensity rescaling based on median T1w/T2w-ratio values in those facial regions yields calibrated T1w/T2w-ratio images. Mean values in lobar regions are evaluated using standard statistical analysis to investigate their interaction with age at scan. Results: Several lobes have strongly positive significant interactions with the computed T1w/T2w-ratio. Most do not show sex effects. A few regions show no measurable effects, such as cingulate and CC areas, which we attribute to sample size and measurement variability. Conclusions: We developed and evaluated a novel way to estimate white matter myelin content for use in studies of brain white matter development.

9417-63, Session PSWed

Subcortical shape and volume abnormalities in an elderly HIV+ cohort

Benjamin Wade, Univ. of California, Los Angeles (United States); Victor Valcour, Univ. of California, San Francisco (United States); Edgar Busovaca, Pardis Esmaeili-Firidouni, Columbia Univ. Medical Ctr. (United States); Shantanu H. Joshi, Univ. of California, Los Angeles (United States); Yalin Wang, Arizona State Univ. (United States); Paul M. Thompson, Univ. of California, Los Angeles (United States)

Over 50% of HIV+ individuals show significant impairment in psychomotor functioning, processing speed, working memory and attention [1, 2]. Patients receiving combination antiretroviral therapy may still have subcortical atrophy, but the profile of HIV-associated brain changes is poorly understood. With parametric surface-based shape analyses, we mapped the 3D profile of subcortical morphometry in 63 elderly HIV+ subjects (4 female; age=65.35 ± 2.21) and 31 uninfected elderly controls (2 female; age=64.68 ± 4.57) scanned with MRI as part of a San Francisco Bay Area study of elderly people with HIV. We also investigated an association of morphometry with nadir CD4 counts among HIV+ participants.

FreeSurfer was used to segment the thalamus, caudate, putamen, pallidum, hippocampus, amygdala, accumbens, brainstem, callosum and ventricles from brain MRI scans. To study subcortical shape, we analyzed: (1) the Jacobian determinant (JD) indexed over structures' surface coordinates and (2) radial distances (RD) of structure surfaces from a medial curve. A JD less than 1 reflects regional tissue atrophy and greater than 1 reflects expansion.

After correcting for age, sex, intracranial volume and multiple comparisons, JD maps identified significantly atrophied regions of the right anterior-lateral caudate, left dorsolateral thalamus and right posterior-medial thalamus in HIV+ participants. Volumetrically, HIV+ participants showed significant decreases in the bilateral thalami, left pallidum and corpus callosum along with enlarged left lateral, third and fourth ventricles. Our results show subcortical brain differences in HIV+ subjects in both shape and volumetric domains.

Integrating histology and MRI in the first digital brain atlas of the common squirrel monkey, Saimiri sciureus

Peizhen Sun, Prasanna Parvathaneni, Kurt G. Schilling, Yurui Gao, Vaibhav A. Janve, Adam M. Anderson, Bennett A. Landman, Vanderbilt Univ. (United States)

This effort is a continuation of development of a digital brain atlas of the common squirrel monkey, Saimiri sciureus, a New World monkey with functional and microstructural organization of central nervous system similar to that of humans. Here, we present the integration of histology with multi-modal magnetic resonance imaging (MRI) atlas constructed from the brain of an adult female squirrel monkey. The central concept of this work is to use block face photography to establish an intermediate coordinate system which preserves the high in-plane resolution of histology while enabling 3D correspondence with MRI. In vivo MRI acquisitions include high resolution T2*-weighted structural imaging (300 ?m isotropic) and low resolution diffusion tensor imaging (600 ?m isotropic). Ex vivo MRI acquisitions include high resolution T2*-weighted structural imaging and high resolution diffusion tensor imaging (both 300 ?m isotropic). Cortical regions were manually annotated on the co-registered volumes based on published histological sections in-plane. We describe the mapping of histology and MRI based data of the common squirrel monkey and construction of a viewing tool that enables online viewing of these datasets. The previously described atlas provides the means of deforming histology to the MRI space, thus adding information at the histological level to the MRI volume. This paper presents the mapping of a single 2D block face image as a proof of concept and this can be extended to map the atlas space in a 3D coordinate system and can be loaded to an eXtensible Neuroimaging Archive Toolkit (XNAT) system for further use.

A novel approach to motion correction for ASL images based on brain contours

Giacomo Tarroni, Marco Castellaro, Univ. degli Studi di Padova (Italy); Carlo Boffano, Maria Grazia Bruzzone, Fondazione I.R.C.C.S. Istituto Neurologico Carlo Besta (Italy); Alessandra Bertoldo, Enrico Grisan, Univ. degli Studi di Padova (Italy)

Motion correction in Arterial Spin Labelling (ASL) is essential to accurately assess brain perfusion. Motion correction techniques are usually based on intensity-related information, which might be unreliable in ASL due to local intensity differences between control and labelled acquisitions and to non-uniform volume magnetization caused by background-suppressed acquisition protocols. Accordingly, a novel motion correction technique based only on brain contour points is presented and tested against a widely used intensity-based technique (MCFLIRT).

The proposed Contour-Based Motion Correction (CBCM) technique relies on image segmentation (to extract brain contour point clouds) and on the Iterative Closest Point algorithm (to estimate the roto-translation required to align them). At variance with other approaches based on point clouds alignment, the local 3D curvature is also computed for each contour point and used as an additional coordinate to increase the accuracy of the alignment. The technique has been tested along with MCFLIRT on a database of randomly roto-translated brain volumes. Several error metrics have been computed and compared between the two techniques. The results show that the proposed technique is able to achieve a higher accuracy than MCFLIRT without any intensity-dependent information.

Resting fMRI measures are associated with cognitive deficits in schizophrenia assessed by the MATRICS consensus cognitive battery

Hao He, Dept. of Electronic and Computer Engineering, University of New Mexico, Albuquerque, NM, USA, 87131 (United States); Juan Bustillo, The Univ. of New Mexico (United States); Yuhui Du, Qingbao Yu, The Mind Research Network (United States); Thomas Jones, The Univ. of New Mexico (United States); Tianzi Jiang, Brainnetome Ctr. & National Lab. of Pattern Recognition, Institute of Automation (China); Vince D. Calhoun, The Mind Research Network (United States) and The Univ. of New Mexico (United States); Jing Sui, Brainnetome Ctr. & National Lab. of Pattern Recognition, Institute of Automation (China)

The cognitive deficits of schizophrenia are largely resistant to current treatment, thus are a life-long burden of the illness. The MATRICS Consensus Cognitive Battery (MCCB) provides a reliable and valid assessment of cognition at all cognitive domains for schizophrenia; however, in resting-state fMRI, both the functional connectivity and spatial alterations specifically associated with MCCB have not been examined. In this paper, the interrelationships between MCCB and the abnormalities seen in two types of functional measures from resting-state fMRI—fractional amplitude of low frequency fluctuations (fALFF) and functional connectivity maps were investigated in data from 47 schizophrenia patients and 50 age-matched healthy controls. First, the fALFF maps were decomposed by independent component analysis (ICA) and the component showing the highest correlation with MCCB composite scores was selected. Second, the whole brain was segmented based on AAL atlas and the functional connectivity (FC) matrix was calculated for each subject. The node-pairs with most significant correlations with MCCB were displayed and spatially overlapped with the previous fALFF component of interest. Interestingly, the FC nodes showing significant correlations with MCCB are in well agreement with the activated regions with highest Z values in fALFF component. It demonstrated Increased cognitive performance associated with higher fALFF values (intensity of regional spontaneous brain activity) in thalamus, striatum, superior temporal gyrus (STG) but lower fALFF values in dosal prefrontal gyrus. Our results support the view that functional deficits in distributed cortico-striato-thalamic circuits may account for several aspects of cognitive impairment in schizophrenia.

Remote 3D oxygen saturation imaging for wound screening

Mangai Prabakar, Young-Jin Jung, Florida International Univ. (United States)

Wound monitoring enables 6.5 million patients (who suffer from chronic wounds) to take charge of their wound management under clinical guidance. It is of great importance for evidence based clinical service. Although non-contact based near-infrared (NIR) optical imaging devices with LED source has been successfully developed for wound monitoring in our research group recently, it could only provide 2D hemodynamic imaging on the tissue surface. In current study, we developed a novel optical scanner with laser source that can estimate the 3D oxygen saturation imaging of superficial tissue based on imaging sensors with multi wavelength (650nm – 850nm) NIR laser sources. The NIR laser beam sequentially scanned on the tissue surface to measure the absorbed and scattered NIR light and the 3D tissue surface geometry. The measured surface geometry and NIR light data was applied to the Approximate Extended Kalman Filter (AEKF) algorithm in order to reconstruct the 3D oxygen saturation imaging. To estimate

the potential of clinical translation, the preliminary human subject study was performed. In the preliminary human study, a simple cuff experiment conducted by changing the cuff pressure from 0 to 120mmhg on the upper arm. The reconstructed 3D oxygen saturation imaging of superficial tissue up to 1 cm depth shows the reasonable pattern according to upper arm occlusion. The results demonstrate that novel 3D optical scanner for oxygen saturation imaging can be prominent tool to provide quantitative and objective evidence for clinical wound screening.

9417-68, Session PSWed

Fiber based in-vivo imaging of epithelial FAD fluorescence: experiments and simulations

Bala Nivetha Kanakaraj, Sujatha Narayanan Unni, Indian Institute of Technology Madras (India)

Fluorescence from endogenous fluorophores has been emerging as a promising biomarker for tissue discrimination resulting the noninvasive screening to understand the biochemical and morphological variations in tissues associated with cancer development. We have developed a scan based fiber optic probe system to image increased fluorescence from epithelial tissues under conditions mimicking dysplasia surrounded by normal tissues. Experiments were conducted on optical phantoms mimicking epithelial tissues excited by 450nm LED source. The spectral emission from the sample is collected via optical fibers and the imaging is performed by scanning the sample using a translation stage at desired resolution. Monte Carlo simulations were also performed by devising an optical model corresponding to epithelial tissue and the results were correlated with experimental fluorescence measurements. This whole field imaging approach could be useful for in vivo assessment of tissue pathologies based on autofluorescence and can give a better quantitative approach for estimation of tissue properties by correlating the experimental and simulated data.

9417-69, Session PSWed

Quantitative assessment and 3D modeling of the maturation of infant epidermis using confocal reflectance microscopy and tissue architecture analysis

Martial Guillaud, The BC Cancer Agency Research Ctr. (Canada); Zhaoyang Chen, British Columbia Cancer Agency (Canada) and The BC Cancer Agency Research Ctr. (Canada); Jalil Bensaci, Georgios N. Stamatas, Johnson & Johnson Consumer France S.A.S. (France)

Introduction & Objectives: During the first years of life infant skin structure, function, and composition are undergoing a maturation process. The aim of this work is to uncover how epidermal tissue topology changes during this time.

Materials & Methods: Using confocal reflectance microscopy data, we imaged the upper arms of healthy infants aged 1, 2, and 3 years and adults (at least 10 subjects per group). Using semi-automated image analysis algorithms, cells centers were identified at different depths corresponding to the levels of the stratum granulosum (SG) and stratum spinosum (SS). Using Voronoi diagram and other sub-graphs such as Delaunay graph and Minimum Spanning Tree, several geometrical and topological features are calculated. A statistical 3D extrapolation-modeling algorithm is then applied to generate from these 2D features a 3D graphical representation of the skin epithelium.

Results: Infant cell density is higher than adult and decreases with age at both strata examined. In the SG, the cell area and perimeter, the average distance of the nearest neighbors, and the average segment length of the

minimum spanning tree increase with age, while these parameters remain constant for the SS. In both layers and for all ages, the distribution of the number of nearest neighbors is typical of a cooperator network architecture found in other non-cancerous epithelial tissues.

Conclusions: Maturation process of the infant skin in the early years of live can be quantitatively assessed by topological parameters. The differences between infant and adult epidermis are more pronounced at the SG than the SS. Topological signature of cell cooperation process is evident for all cases of healthy skin

9417-70, Session PSWed

Digital speckle pattern interferometry based anomaly detection in breast mimicking phantoms: a pilot study

K. Udayakumar, Sujatha Narayanan Unni, A. R. Ganesan, Indian Institute of Technology Madras (India)

Early identification of subsurface anomalies in breast can improve the patient survival rate. Clinically approved breast screening modalities may either have body ionizing effect / causes pain to the body parts / involves body contact / increased cost. In this paper, a non-invasive, whole field Digital Speckle Pattern Interferometry (DSPI) technique is used to study normal and abnormal breast mimicking tissue phantoms. An agar based normal breast mimicking phantom is prepared and illuminated with HeliumNeon (HeNe) laser; resulting speckle pattern is captured and stored as a reference image. Using customized loading system, a known pressure is applied to the phantom. Deformation fringe pattern generated by the normal phantom is captured using zoom lens attached CCD camera and displayed in a computer monitor. A measured size and shape of abnormality made with double the concentration of agar as in normal phantom is embedded in the subsurface of normal phantom. This abnormality embedded phantom is considered as breast with an anomaly. Using the same set-up, out of plane speckle pattern interferometry configuration, experiments are carried out and the non uniformity observed in the fringes clearly shows the anomaly location in the abnormal phantom. Phantoms with similar dimensions are modeled and deformation analysis is carried out using Finite Element Method (FEM). The experimental results of deformation fringe patterns for normal and abnormal are compared with the deformation profiles obtained using finite element analysis of the sample under similar loading conditions. Both experimental and simulation results are correlated each other for abnormality location.

9417-72, Session PSWed

Fourier transform infrared spectroscopy to identify the contribution of nuclei to cellular spectra in different phases of the cell cycle

Saumya Tiwari, Xinying Zong, Sarah E. Holton, Kannanganattu V. Prasanth, Rohit Bhargava, Univ. of Illinois at Urbana-Champaign (United States)

Neoplasia involves active cellular growth which involves processes like DNA replication and transcription to produce proteins for cell division. These chemical changes are important markers of actively dividing cells and are important to formulating chemical approaches to disease diagnoses. When examining biopsy sections using Fourier transform infrared (FT-IR) spectroscopy to diagnose metabolic and disease processes, careful analysis of cell growth becomes important since physiologic abnormality signatures may be confused with normal cell cycle processes. No study using infrared spectroscopy, however, has reported exclusive signals from cell nuclei. Nuclei hold critical information about the phase of cell and its capacity to divide but their signals are suppressed by cytoplasmic signals during IR spectral data acquisition from cells. Therefore, we sought to separate nuclear signals

from cytoplasmic signals and identify key spectral differences that could be used to recognize nuclear signals in cells in different phases of cell cycle. We analyzed whole cells and isolated nuclei from different phases in order to assess the difference in spectra produced after removal of cytoplasmic background and identified key spectral changes in nuclei in different phases of cell cycle. We observed that in contradiction to previously held belief that DNA signals are not significant in growth phases of cells, signals due to DNA could be obtained when isolated nuclei from different phases of cell cycle were imaged. The differences in cell cycle phases were more pronounced in nucleic acid regions of nuclei spectra, showing that use of nuclear spectrum can provide additional useful information. These results can help in developing computational models that utilize nuclear spectral information from whole cells and tissues for accurate assessment of biochemical variations and disease.

9417-73, Session PSWed

Semi-automated 2D Bruch's membrane shape analysis in papilledema using spectral-domain optical coherence tomography

Jui-Kai Wang, The Univ. of Iowa (United States); Patrick A. Sibony, Stony Brook Medicine (United States); Randy H. Kardon, Iowa City VA Medical Ctr. (United States) and The Univ. of Iowa (United States); Mark J. Kupersmith, The New York Eye and Ear Infirmary (United States); Mona K. Garvin, Iowa City VA Medical Ctr. (United States) and The Univ. of Iowa (United States)

Recently, it has been observed that Bruch's membrane (BM) and the retinal pigment epithelium (RPE) as visible from optical coherence tomography (OCT) often has an inverted-U shape (toward the vitreous) in cases of optic nerve edema due to raised intracranial pressure. The BM/RPE shape has been quantified using a statistical-shape-model approach; however, to date, the approach has involved the tedious and time-consuming manual placement of landmarks and correspondingly, only the shape (and shape changes) of a limited number of patients has been studied. In this work, we first present a semi-automated approach for the extraction of 20 landmarks along the BM from an optic-nerve-head (ONH) centered OCT slice from each patient. In the approach, after the manual placement of the two Bruch's membrane opening (BMO) points, the remaining 18 landmarks are automatically determined using a graph-based segmentation approach. We apply the approach to the OCT scans of 116 patients (at baseline) enrolled in the Idiopathic Intracranial Hypertension Treatment Trial and generate a statistical shape model using principal components analysis. Using the resulting shape model, the coefficient (shape parameter) corresponding to the second principal component (eigenvector) for each set of landmarks indicates the degree the BM/RPE is oriented towards the vitreous. Using a subset of 20 patients, we compare the shape parameter computed using this semi-automated approach with the resulting shape parameter when (1) all landmarks are specified manually (Experiment I); and (2) a different expert specifies the two BMO points (Experiment II). In each case, a correlation coefficient ≥0.99 is obtained.

9417-74, Session PSWed

Development of color micro optical-CT: evaluation using phantom and biological samples

Chika Murata, Atsushi Teramoto, Chiyuki Kaneko, Fujita Health Univ. (Japan); Hiroshi Fujita, Gifu Univ. School of Medicine (Japan)

Micro-optical computed tomography (CT) is a method for performing image reconstruction using microscopic images to obtain tomographic images of small samples. Compared with conventional observation methods, it offers the possibility to obtain tomograpic images without distortion, and create three-dimensional images. However, micro optical-CT system which developed previously outputs monochrome images,while useful color information could not be obtained from the analysis of the sample. Therefore, we focused on the features that simplify the wavelength measurement of visible light, and developed a color micro optical-CT system that can obtain color tomographic images. In this study, we acquired tomographic images of phantom and biological samples, and evaluated its usefulness. In this system, a digital single-lens reflex camera was used as a detector that was connected to a stereoscopic microscope, and projection images were obtained by rotating the sample. The sample was fixed in the test tube by carrageenan. The projection images were obtained from various projection angles followed by decomposing the R, G and B components. Subsequently, we performed image reconstruction for each component using filtered back projection. Finally, color tomographic image was obtained by combining the three-color component images. In the experiments, we scanned a color phantom and biological samples and evaluated the color and shape reproducibility. As a result, it was found that the color and shape of the tomographic images were similar to those of the samples. These results indicate that the proposed system may be useful to obtain the three-dimensional color structure of biological samples.

9417-75, Session PSWed

Coherent noise remover for optical projection tomography

Liangliang Shi, Di Dong, Yujie Yang, Jun Wang, Institute of Automation (China); Alicia Arranz, ETH Zürich (Switzerland); Jorge Ripoll, Univ. Carlos III de Madrid (Spain); Jie Tian, Institute of Automation (China)

Optical Projection Tomography (OPT) is a 3-Dimentional (3D) imaging technique for small specimens between 1mm and 10mm in size. Due to its high resolution and whole-body imaging ability, OPT has been widely used for imaging of small specimens such as murine embryos, murine organs, zebra fish, and plant sections. During an OPT imaging experiment, the ring artifacts are very common which severely impact the image quality of OPT. A ring artifact is caused by a bad pixel on the camera, or impurities on surface of lens and index matching vessel. Here we term these noises as coherent noise because they stay in the same image region during an OPT experiment. Currently, there is still no effective method to remove coherent noises. To address this problem, we propose a novel method to suppress the coherent noises before 3D OPT reconstruction. Our method consists of two steps: 1) find bad pixel positions on a blank image without specimen by using threshold segmentation, then fix the bad pixels on the projection image by using average of their neighbor pixels, 2) remove remained coherent noises on the sinogram by using Variational Coherent noise Remover (VSNR) method. After the two steps, lots of method can be used to generate the tomographic slices from the modified sinograms. We apply our method to mouse heart imaging with our home-made OPT system. The experimental results show that our method has a good suppression on coherent noise and greatly improves the image quality. The innovation of our method is that we remove coherent noise automatically from both projection image and sinogram and they complement each other.

9417-76, Session PSWed

Signal enhancement in optical projection tomography via virtual high dynamic range imaging of single exposure

Yujie Yang, Di Dong, Liangliang Shi, Institute of Automation (China); Jun Wang, Harbin Univ. of Science and Technology (China); Jorge Ripoll, Univ. Carlos III de

Madrid (Spain); Jie Tian, Institute of Automation (China)

Optical projection tomography (OPT) is a mesoscopic scale optical imaging technique for specimens between 1mm and 10mm. OPT has been proven to be immensely useful in a wide variety of biological applications, such as developmental biology and pathology, but its shortcomings in imaging specimens containing widely differing contrast elements are obvious. The longer exposure for high intensity tissues may lead to over saturation of other areas, whereas a relatively short exposure may cause similarity with surrounding background. In this paper, we propose an approach to make a trade-off between capturing weak signals and revealing more details for OPT imaging. This approach consists of three steps. Firstly, the specimens are merely scanned in 360 degrees above a normal exposure but non-overexposure to acquire the projection data. This reduces the photo bleaching and pre-registration computation compared with multiple different exposures in conventional high dynamic range (HDR) imaging method. Secondly, three virtual channels are produced for each projection image based on the histogram distribution to simulate the low, normal and high exposure images used in the traditional HDR technology in photography. Finally, each virtual channel is normalized to the full gray scale range and three channels are recombined into one image using weighting coefficients optimized by a standard eigen-decomposition method. After applying our approach on the projection data, filtered back projection (FBP) algorithm is carried out for 3-dimentional reconstruction. The neonatal wild-type mouse paw has been scanned to verify this approach. Results demonstrated the effectiveness of the proposed approach.

9417-77, Session PSWed

Towards Myocardial Contraction Force Image Reconstruction for Heart Disease Assessment and Intervention Planning

Seyyed Mohammad Hassan Haddad, The Univ. of Western Ontario (Canada); Maria Drangova, Western Univ. (Canada); James A. White, University of Calgary (Canada); Abbas Samani, The Univ. of Western Ontario (Canada)

The objective of this work is to develop a technique to determine the extent and intensity of local damages to cardiac tissue caused by ischemic injuries for evaluating regional functionality of the myocardium. Such a technique can enable cardiologist to discriminate between reversible and irreversible ischemic injuries and devise appropriate revascularization therapy in case of reversible lesions. To this end, a number of imaging techniques have been developed and, to our knowledge, none of them assess regional cardiac functionality based on a straightforward mechanical measure such as local cardiac contraction forces. It is noteworthy that sufficient contraction force generation can be regarded as a direct and reliable criterion for regional analysis of the tissue functionality. As such, a novel imaging technique is being developed for quantification of local myocardial contraction forces. In this technique, cardiac contraction force distribution is attained through solving an inverse problem within an optimization framework which uses iterative forward mechanical modelling of the myocardium. Hence, a forward mechanical model of the myocardium which is computationally efficient, robust, and adaptable to diverse pathophysiological conditions is necessary for this development. As such, this paper is geared towards developing a novel mechanical model of the healthy and pathological myocardium which considers all aspects of the myocardial mechanics including hyperelasticity, anisotropy, and active contraction force. In this investigation, two major parts, including background tissue and reinforcement bars (fibers) have been considered for modelling the myocardium. The model was implemented using finite element (FE) approach and demonstrated very good performance in simulating the normal and infarcted left ventricle (LV) contractile function.

9417-79, Session PSWed

Treatment planning for image-guided neuro-vascular interventions using patient-specific 3D printed phantoms

Megan K. Russ, Ryan P. O'Hara, Swetadri Vasan Setlur Nagesh, Maxim Mokin, Carlos Jimenez, Adnan H. Siddiqui, Daniel R. Bednarek, Stephen Rudin, Ciprian N. Ionita, Univ. at Buffalo (United States)

Minimally invasive endovascular image-guided interventions (EIGIs) are the preferred procedures for treatment of a wide range of vascular disorders. Despite benefits including reduced trauma and recovery time, EIGIs have their own challenges. Remote catheter actuation and challenging anatomical morphology may lead to erroneous endovascular device selections, delays or even complications such as vessel injury. EIGI planning using 3D phantoms would allow interventionists to become familiarized with the patient vessel anatomy by first performing the planned treatment on a phantom under standard operating protocols. In this study the optimal workflow to obtain such phantoms from 3D data for interventionalist to practice prior to an actual procedure was investigated. Patient-specific phantoms and phantoms presenting a wide range of challenging geometries were created. Computed Tomographic Angiography (CTA) data was uploaded into a Vitrea 3D station which allows segmentation and resulting stereo-lithographic files to be exported. The files were uploaded using processing software where pre-loaded vessel structures were included to create a closed-flow vasculature having structural support. The final file was printed, cleaned, connected to a flow loop and placed in an angiographic room for EIGI practice. Various Circle of Willis and cardiac arterial geometries were used. The phantoms were tested for ischemic stroke treatment, distal catheter navigation, aneurysm stenting and cardiac imaging under angiographic guidance. This method should allow for adjustments to treatment plans to be made before the patient is actually in the procedure room and enabling reduced risk of peri-operative complications or delays.

9417-81, Session PSWed

Aneurysm flow characteristics in realistic carotid artery aneurysm models induced by proximal virtual stenotic plaques: a computational hemodynamics study

Marcelo A. Castro, Consejo Nacional de Investigaciones Científicas y Técnicas (Argentina); Nora L. Peloc, Univ. Tecnológica Nacional (Argentina); Aichi Chien, Univ. of California, Los Angeles (United States); Ezequiel Goldberg, Univ. Tecnológica Nacional (Argentina); Christopher M. Putman, Texas Neurointerventional Surgery Associates (United States); Juan R. Cebral, George Mason Univ. (United States)

Cerebral aneurysms may rarely coexist with a proximal artery stenosis. In that small percent of patients, such coexistence poses a challenge for interventional neuroradiologists and neurosurgeons to make the best treatment decision. According to previous studies, the incidence of cerebral aneurysms in patients with internal carotid artery stenosis is not greater than five percent, where the aneurysm is usually incidentally detected, being about two percent for aneurysms and stenoses in the same cerebral circulation. Those cases pose a difficult management decision for the physician. Case reports showed patients who died due to aneurysm rupture months after endarterectomy but before aneurysm clipping, while others did not show any change in the aneurysm after plaque removal, having optimum outcome after aneurysm coiling. The aim of this study is to investigate the intraaneurysmal hemodynamic changes before and after treatment of stenotic plaque. Virtually created moderate stenoses in

vascular models of internal carotid artery aneurysm patients were consider in a number of cases reconstructed from three dimensional rotational angiography images. The strategy to create those plaques was based on parameters analyzed in a previous work where idealized models were considered, including relative distance and stenosis grade. Ipsilateral and contralateral plaques were modeled. Wall shear stress and velocity pattern were computed from finite element pulsatile blood flow simulations. The results may suggest that wall shear stress changes depend on relative angular position between the aneurysm and the plaque..

9417-82, Session PSWed

A reconstruction method of intra-ventricular blood flows using color flow ultrasound: a simulation study

Jaeseong Jang, Yonsei Univ. (Korea, Republic of); Chi Young Ahn, Kiwan Jeon, National Institute for Mathematical Sciences (Korea, Republic of); Jung-il Choi, Changhoon Lee, Jin Keun Seo, Yonsei Univ. (Korea, Republic of)

A reconstruction method is proposed here to quantify the distribution of blood flow velocity fields inside the left ventricle from color Doppler echocardiography measurement. From 3D incompressible Navier-Stokes equation, a 2D incompressible Navier-Stokes equation with a mass source term is derived to utilize the measurable color flow ultrasound data in a plane along with the moving boundary condition. The proposed model reflects out-of-plane blood flows on the imaging plane through the mass source term. For demonstrating a feasibility of the proposed method, we have performed numerical simulations of the forward problem and numerical analysis of the reconstruction method. First, we construct a 3D moving LV region having a specific stroke volume. To obtain synthetic intra-ventricular flows, we performed a numerical simulation of the forward problem of Navier-Stokes equation inside the 3D moving LV, computed 3D intra-ventricular velocity fields as a solution of the forward problem, projected the 3D velocity fields on the imaging plane and took the inner product of the 2D velocity fields on the imaging plane and scanline directional velocity fields for synthetic scanline directional projected velocity at each position. The proposed method utilized the 2D synthetic projected velocity data for reconstructing LV blood flow. By computing the difference between synthetic flow and reconstructed flow fields, we obtained the averaged pointwise errors of 0.06 m/s and 0.02 m/s for u- and v-components, respectively.

9417-83, Session PSWed

Consistent and reproducible positioning in longitudinal imaging for phenotyping genetically modified swine

Emily Hammond, Samantha K. Dilger, Nicholas Stoyles, Alexandra Judisch, John Morgan, Jessica C. Sieren, The Univ. of Iowa (United States)

Recent growth of genetic disease models in swine has presented the opportunity to advance translation of developed imaging protocols, while characterizing the genotype to phenotype relationship. Repeated imaging with clinical modalities provides non-invasive detection, diagnosis and monitoring of disease to accomplish these goals; however, longitudinal scanning requires repeatable and reproducible positioning of the animals. A modular positioning unit was designed to provide a stable base to host the animal while under anesthesia, during scanning and while in-transit. Post ventilation and sedation, animals were placed supine in the unit and monitored for consistent vitals. Comprehensive imaging was performed with a computed tomography (CT) chest-abdomen-pelvis scan at each screening time point. Preliminary results were obtained with four animals at two

time points. Images were rigidly registered and assessment of alignment was quantified via ten pairs of corresponding points on the skeleton. The developed unit aided in a skeletal alignment within an average of 12 mm for all four subjects providing a strong foundation for developing qualitative and quantitative methods of disease tracking.

9417-84, Session PSWed

Mid-callosal plane determination using preferred directions from diffusion tensor images

André L. Costa, Leticia Rittner, Roberto A. Lotufo, Simone Appenzeller, Univ. Estadual de Campinas (Brazil)

The corpus callosum is the major white matter structure found in the mammalian brain. There are many studies relating the corpus callosum attributes to patient characteristics, cerebral diseases and psychological disorders. Most of those studies rely on 2D analysis of the corpus callosum in the mid–sagittal plane. However, it is common to find conflicting results between studies, once most ignore methodological issues and define the mid–sagittal plane based on precary or invalid criteria with respect to the corpus callosum analysis. In this work we propose a novel method to determine a mid–callosal plane, instead of a mid–sagittal one, by using the corpus callosum internal preferred diffusion directions obtained from diffusion tensor images. Our method has great potential to enable corpus callosum analysis to be comparable between subjects and repeatable for the same subject. The method main concepts are presented, and preliminary results with one pair of images from the same subject obtained under same conditions show that it is valid. Robustness tests and improvements are currently under development and shall be concluded for the final paper version.

9417-85, Session PSWed

Feature transformation of neural activity with sparse and low-rank decomposition

Kang-Yu Ni, James Benvenuto, Rajan Bhattacharyya, Rachel Millin, HRL Labs., LLC (United States)

We propose a novel application of the sparse and low-rank (SLR) decomposition method to decode cognitive states for concept activity measured using fMRI BOLD. Current decoding methods attempt to reduce the dimensionality of fMRI BOLD signals to increase classification rate, but do not address the separable issues of multiple noise sources and complexity in the underlying data. Our feature transformation method extends SLR to separate task activity from the resting state and extract concept specific cognitive state.

The key concept is that the data from these initially noisy high-dimensional complex neural signals often contain a foreground component and a background component, in addition to noise. The SLR method efficiently decomposes a low-rank matrix and sparse matrix from their sum, the input data matrix. The background component can represent cognitive state related to resting state activity or normal ongoing maintenance activity (e.g., default mode network activity) while the foreground activity might represent task related cognitive state. We attempt to separate these components to enable more accurate classification of cognitive states, especially when the signal of interest pertains to either foreground or background activity.

We demonstrate that our feature transform method is able to significantly increase the accuracy of classification on the Mitchell Science 2008 fMRI BOLD data. The sparse component of SLR is used as the task related cognitive state feature. To test this feature, we perform single trial cognitive state classification for individual concepts using linear SVM. We observe that for a large range of sparsity, using the extracted feature, the classification rate increases significantly, showing the potential to extract the exemplar-activated voxels.

9417-86, Session PSWed

Toward content based image retrieval with deep convolutional neural networks

Judah E. S. Sklan, Andrew J. Plassard, Daniel Fabbri, Bennett A. Landman, Vanderbilt Univ. (United States)

Content-based image retrieval (CBIR) offers the potential to identify similar case histories, understand rare disorders, and eventually, improve patient care. Recent advances in database capacity, algorithm efficiency, and deep Convolutional Neural Networks (dCNN), a machine learning technique, have enabled great CBIR success for general photographic images. Here, we investigate applying the leading ImageNet CBIR technique to clinically acquired medical images captured by the Vanderbilt Medical Center. Briefly, we (1) constructed a dCNN with four hidden layers, reducing dimensionality of an input scaled to 128x128 to an output encoded layer of 4x384, (2) trained the network using back-propagation with 1 million random magnetic resonance (MR) and computed tomography (CT) images, (3) labeled an independent set of 2100 images, and (4) evaluated classifiers on the projection of the labeled images into manifold space. Quantitative results were disappointing (averaging a true positive rate of only 20%); however, the data suggest that improvements would be possible with more evenly distributed sampling across labels and potential re-grouping of label structures. This preliminary effort at automated classification of medical images with ImageNet is promising, but shows that more work is needed beyond direct adaptation of existing techniques.

9417-87, Session PSWed

Effects of frame rate and image resolution on pulse rate measured using multiple camera imaging photoplethysmography

Ethan Blackford, Ball Aerospace & Technologies Corp. (United States); Justin Estepp, Air Force Research Lab. (United States) and Wright-Patterson Air Force Base (United States)

Non-contact, imaging photoplethysmography uses cameras to facilitate measurements including pulse rate, pulse rate variability, respiration rate, and blood perfusion by measuring characteristic changes in light absorption at the skin's surface resulting from changes in blood volume in the superficial microvasculature. Several factors may affect the accuracy of the physiological measurement including imager frame rate, resolution, compression, lighting conditions, image background, participant skin tone, and participant motion. Before this method can gain wider use outside basic research settings, its constraints and capabilities must be well understood. Recently, we presented a novel approach utilizing a synchronized, nine-camera, semicircular array backed by measurement of an electrocardiogram and fingertip reflectance photoplethysmogram. Twenty-five individuals participated in six, five-minute, controlled head motion artifact trials in front of a black and dynamic color backdrop. Increasing the input channel space for blind source separation using the camera array was effective in mitigating error from head motion artifact. Herein we present the effects of lower frame rates at 60 and 30 (reduced from 120) frames per second and reduced image resolution at 329x246 pixels (one-quarter of the original 658x492 pixel resolution) using bilinear and zero-order downsampling. This is the first time these factors have been examined for a multiple imager array and align well with previous findings utilizing a single imager. Examining windowed pulse rates, there is little observable difference in mean absolute error or error distributions resulting from reduced frame rates or image resolution, thus lowering requirements for systems measuring pulse rate over sufficient length time windows.

9417-88, Session PSWed

Converting multiple tomosynthesis images from a clinical positron emission mammography system to a single tomographic image for preclinical studies

Matthew A. Lewis, The Univ. of Texas Southwestern Medical Ctr. at Dallas (United States)

The CMR Naviscan Flex Solo II Positron Emission Mammography System is an FDA-approved modality for breast imaging. The system uses 2 planar volumetric detectors in coincidence, and since there is no rotation the resolution is anisotropic due to the tomosynthesis nature of the image reconstruction. The in-plane resolution of the Naviscan PEM has been reported in the range of 1.6 to 2.4 mm, while the out-of-plan full width-half maximum resolution is poorer at 8.0 ± 1.0 mm. Monte Carlo simulations in GATE indicate that the system sensitivity of the PEM when used for preclinical imaging may be competitive with dedicated small animal PET systems. To use the clinical PEM camera as a preclinical PET scanner, the spatially-varying point-spread-function is measured in an automated manner, and then utilized by standard super-resolution image restoration methods to combine tomosynthesis images with different degrees of rotation. The proposed method is analogous to reconstructing projection-based time-of-flight images. In this work, techniques and methods for accomplishing fully 3D imaging on a PEM system are described and characterized using phantoms with comparison to preclinical PET imaging.

9417-89, Session PSWed

Tooth segmentation system with intelligent editing for cephalometric analysis

Shoupu Chen, Carestream Health, Inc. (United States)

Cephalometric analysis is the study of the dental and skeletal relationship for the head, and it is used as an assessment and planning tool for improved orthodontic treatment of a patient. Conventional cephalometric analysis identifies bony and soft tissue landmarks in 2D cephalometric radiographs, in order to diagnose facial features and abnormalities prior to treatment, or to evaluate the progress of treatment. Recent studies in orthodontics indicate that there are persistent inaccuracies and inconsistencies in results provided using conventional 2D cephalometric analysis. Obviously, plane geometry is inappropriate for analyzing anatomical volumes and their growth; only a 3D analysis is able to analyze the anatomical maxillofacial complex, which requires computing inertia systems for individual teeth. This paper proposes a system for semi-automatically segmenting teeth from cone beam computerized tomography volumes with two distinct features, including an intelligent user-input interface for automatic background seed generation, and a graphics processing unit acceleration mechanism for parallel GrowCut processing. Preliminary results show a satisfying average DICE score of 0.92, with the use of the current system, by 15 novice users who segmented a randomly sampled tooth set. The average GrowCut processing time was a few seconds per tooth excluding user interaction time. The application of segmented teeth in 3D cephalometric analysis is also presented.

9417-90, Session PSWed

Non-invasive pulmonary blood flow analysis and blood pressure mapping derived from 4D flow MRI

Michael Delles, Karlsruher Institut für Technologie (Germany); Fabian Rengier, Univ. Heidelberg (Germany) and Deutsches Krebsforschungszentrum (Germany);

Yoo-Jin Azad, Sebastian Bodenstedt, Karlsruher Institut für Technologie (Germany); Hendrik von Tengg-Kobligk, Univ. Heidelberg (Germany) and Deutsches Krebsforschungszentrum (Germany) and Inselspital Bern (Switzerland); Sebastian Ley, Univ. Heidelberg (Germany); Roland Unterhinninghofen, Karlsruher Institut für Technologie (Germany); Hans-Ulrich Kauczor, Univ. Heidelberg (Germany); Rüdiger Dillmann, Karlsruher Institut für Technologie (Germany)

In diagnostics and therapy control of cardiovascular diseases, detailed knowledge about the patient-specific behavior of blood flow and pressure can be essential. The only method capable of measuring complete time-resolved three-dimensional vector fields of the blood flow velocities is velocity-encoded magnetic resonance imaging (MRI), often denoted as 4D flow MRI. Furthermore, relative pressure maps can be computed from this data source, as presented by different groups in recent years. Hence, analysis of blood flow and pressure using 4D flow MRI can be a valuable technique in management of cardiovascular diseases. In order to perform these tasks, all necessary steps in the corresponding process chain can be carried out in our in-house developed software framework MEDIFRAME. In this article, we apply MEDIFRAME for a study of hemodynamics in the pulmonary arteries of five healthy volunteers. The study included measuring vector fields of blood flow velocities by phase-contrast MRI and subsequently computing relative blood pressure maps. We visualized blood flow by streamline depictions and computed characteristic values for the left and the right pulmonary artery (LPA and RPA). In all volunteers, we observed a lower amount of blood flow in the LPA compared to the RPA. Furthermore, we visualized blood pressure maps using volume rendering and generated graphs of pressure differences between the LPA, the RPA and the main pulmonary artery. In most volunteers, blood pressure was increased near to the bifurcation and in the proximal LPA, leading to higher average pressure values in the LPA compared to the RPA.

9417-91, Session PSWed

Effect of sample size on multi-parametric prediction of tissue outcome in acute ischemic stroke using a random forest classifier

Nils Daniel Forkert, Univ. of Calgary (Canada); Jens Fiehler, Univ. Medical Ctr. Hamburg-Eppendorf (Germany)

The tissue outcome prediction in acute ischemic stroke patients is highly relevant for clinical routine and research. It has been shown that the combined analysis of diffusion and perfusion MRI datasets using high-level machine learning techniques leads to an improved prediction of final infarction compared to single parameter thresholding. However, most high-level classifiers require a previous training and, until now, it is ambiguous how many subjects are required for this. Therefore, 23 MRI datasets of acute stroke patients with known tissue outcome were used for evaluation in this work. Relative values of diffusion and perfusion parameters as well as the binary tissue outcome were voxel-wisely extracted for all patients and used for training of a random forest classifier. The number of patients used for training set definition was iteratively and randomly reduced from using all 22 other patients to only one other patient. Thus, 22 tissue outcome predictions were generated for each patient using the trained random forest classifiers and compared to the known tissue outcome using the Dice coefficient. Overall, a logarithmic relation between the number of patients used for training set generation and tissue outcome prediction accuracy was found. Quantitatively, a mean Dice coefficient of 0.45 was found for the prediction using the training set consisting of the voxel information from only one other patient, which increases to 0.53 if using all other patients (n=22). Based on extrapolation, 50-100 patients seem like a reasonable tradeoff between tissue outcome prediction accuracy and effort required for data acquisition and preparation.

9417-92, Session PSWed

Automated pipeline to analyze non-contact infrared images of the paraventricular nucleus specific leptin receptor knock-out mouse model

Myriam Diaz Martinez, Masoud Ghamari-Langroudi, Aliya Gifford, Roger Cone, Edward B. Welch, Vanderbilt Univ. Medical Ctr. (United States)

Evidence of leptin resistance is indicated by elevated leptin levels together with other hallmarks of obesity such as a defect in energy homeostasis. As obesity is an increasing epidemic in the US, the investigation of mechanisms by which leptin resistance has a pathophysiological impact on energy is an intensive field of research. However, the manner in which leptin resistance contributes to the dysregulation of energy, specifically thermoregulation, is not known.

The aim of this study was to investigate whether the leptin receptor expressed in paraventricular nucleus (PVN) neurons plays a role in thermoregulation at different temperatures.

Non-contact infrared (NCIR) thermometry was employed to measure surface body temperature (SBT) of non-anesthetized mice with a specific deletion of the leptin receptor in the PVN after exposure to room (25°C) and cold (4°C) temperature. Dorsal side infrared images of wild type (LepRwtwt/sim1-Cre), heterozygous (LepRfloxwt/sim1-Cre) and LepRfloxflox/sim1-Cre mice were collected. Images were input to an automated post-processing pipeline developed in MATLAB to calculate average and maximum SBTs. Linear regression was used to evaluate the relationship between sex, cold exposure and leptin genotype with SBT measurements.

Findings indicate that average SBT has a negative relationship to the LepRfloxflox/sim1-Cre genotype, the female sex and cold exposure. However, max SBT is affected by the LepRfloxflox/sim1-Cre genotype and the female sex.

In conclusion this data suggests that leptin within the PVN may have a neuroendocrine role in thermoregulation and that NCIR thermometry combined with an automated imaging-processing pipeline is a promising approach to determine SBT in non-anesthetized mice.

9417-93, Session PSWed

MR image analysis of upper airway architecture in children with OSAS

Yubing Tong, Jayaram K. Udupa, Drew A. Torigian, Monica M. S. Matsumoto, Univ. of Pennsylvania (United States); Sanghun Sin, Raanan Arens, Children's Hospital at Montefiore (United States)

Mechanisms leading to Obstructive Sleep Apnea Syndrome (OSAS) in obese children are not well understood. We previously analyzed polysomnographic and demographic data to study the anatomical characteristics of the upper airway and body composition in two groups of obese children with and without OSAS, where object volume was evaluated. In this paper, in order to better understand the disease we expand the analysis considering a variety of features that include object-specific features such as size, surface area, shape, and image intensity properties of fourteen objects in the vicinity of the upper airway, as well as inter-object relationships such as distance between objects and correlation between object-specific features. Correlation between different features for the two groups is visualized using heat maps which give an overall idea of the major differences between the two groups in terms of the architecture of the object assembly. Our preliminary results indicate several interesting phenomena: Volumes and surface areas of adenoid and tonsils increase statistically significantly in OSAS. Standardized T2-weighted MR image intensities differ statistically significantly between the two groups, implying that perhaps intrinsic tissue composition undergoes changes in OSAS. The property of object sizes

varying together in normal subjects is mostly lost in OSAS except for object pairs (pharynx, fat pad), (soft palate, tonsils), and (adenoid, fat pad) where it is further enhanced. Generally distances between objects vary together in both groups except that this covariation becomes stronger in OSAS for distances involving mandible and pharynx with other objects.

9417-94, Session PSWed

A new application of electrical impedance spectroscopy for measuring glucose metabolism: a phantom study

Sreeram Dhurjaty, Dhurjaty Electronics Consulting LLC (United States); Yuchen Qiu, Maxine Tan, Hong Liu, Bin Zheng, The Univ. of Oklahoma (United States)

Glucose metabolism relates to biochemical processes in living organisms and plays an important role in diabetes and cancer-metastasis. Although many methods are available for measuring glucose metabolism-activities, from simple blood tests to positron emission tomography, currently there is no a robust and affordable device that enables monitoring of glucose levels in real-time. In this study we tested feasibility of applying a unique resonance-frequency based electronic impedance spectroscopy (REIS) device that has been, recently, developed to measure and monitor glucose metabolism levels using a phantom study. In this new model, a multi-frequency electrical signal sequence is applied and scanned through the subject. When the positive reactance of an inductor, inside the device cancels out the negative reactance of the capacitance of the subject, the electrical impedance reaches a minimum value and this frequency is defined as the resonance frequency. The REIS system has a 24-bit analog-to-digital signal convertor and a frequency-resolution of 100Hz. In the experiment, two probes are placed inside a 100cc container initially filled with distilled water. As we gradually added liquid-glucose in increments of 1cc (250mg), we measured resonance frequencies and minimum electrical signal values (where A/D was normalized to a full scale of 1V). The results showed that resonance frequencies, monotonously, decreased from 243KHz to 178KHz, while the minimum voltages increased from 405mV to 793mV as the added amount of glucose increased from 0 to 5cc. The study demonstrated the feasibility of applying this new REIS technology to measure and/or monitoring glucose levels in real-time in future.

9417-96, Session PSWed

The use of micro-CT image data and additive manufacturing to create a functional hip implant for small animal studies

Adam D. M. Paish, Hristo N. Nikolov, Robarts Research Institute (Canada) and Western Univ. (Canada); Ian D. Welch, Western Univ. (Canada); David W. Holdsworth, Robarts Research Institute (Canada) and Western Univ. (Canada)

Traditionally, orthopaedic research relies on large animal models for testing functional implants and components. However, utilizing small animal models, such as the rat, would be ideal for testing novel surface preparations that aim to promote osseointegration. Recent advances in additive manufacturing, specifically in 3D selective laser melting (SLM), have made it possible to create functional components small enough for testing in rats. Furthermore, image data obtained using micro-computed tomography (micro-CT) can be used to guide the design of custom components for orthopaedic applications. Thus, we propose to design and fabricate novel custom, functional metal-alloy orthopaedic implants for use in a rodent model of partial-hip replacement.

First, a proof of concept was done to evaluate the feasibility of printing miniature metal hip implants. Several copies of a scaled down human

femoral hip prosthesis along with several rat prototypes were 3D printed in 316L stainless steel. SLM was successful in producing virtually identical copies of each implant model. Next, a database of n=25 previously acquired micro-CT image volumes of male Sprague-Dawley rats (390-610g) were analyzed to ascertain the spatial relationship of several key features of the proximal rat femora. Mean measurements of the medullary cavity and femoral neck and head were used to create a novel rat-hip implant in 4 different sizes: mean*0.85 (small), mean*0.9 (medium), mean*1.0 (large) and mean*1.1 (extra-large). The implants created via this method are the first of their kind and lend support to the feasibility of using micro-CT image data to guide the design of custom orthopaedic components.

9417-97, Session PSWed

Bioengineered micro-tissue platform for image-based analysis of cellular behaviors controlled via mechanoregulation

Ki-Hwan Nam, Kye-Sung Lee, Korea Basic Science Institute (Korea, Republic of); Pak Kin Wong, The Univ. of Arizona (United States); Deok-Ho Kim, Univ. of Washington (United States)

Cells are highly sensitive to topographic and mechanical features of the surrounding extracellular matrix environment, and sense and interpret the mechanical cues, such as cell-substrate and cell-cell interactions, and substrate geometry in the microenvironment to regulate their activities and functions. Understanding the effects and relationships between these regulatory factors on cell behaviors is critical for fundamental cell biology and development of novel strategies in tissue engineering and regenerative medicine. Furthermore, most current cell-based assays are 2D-based systems, even though such in vitro assays do not adequately recreate the in vivo complexity of 3D tissues. Inadequate representation of the human tissue environment during a preclinical test can result in inaccurate predictions of compound effects on overall tissue functionality. Numerous studies have shown that cell responses to drugs in 3D culture are improved from those in 2D, with respect to modeling in vivo tissue functionality, which highlights the advantages of using 3D-based models. In this study, we engineered an innovative biomimetic platform using nanotopography and plasma lithographic surface modification in order to guide and promote cancer metastasis, and neuritogenesis and neuronal differentiation, which accurately mimic the physiological and mechanical properties of native tissue samples, and highlight the advantages of using such 3D micro-tissue models over conventional cell-based assays for future biomedical engineering applications. Since substrate topographies, cell geometry, and cell-cell or cell-substrate interactions are commonly encountered in the cell microenvironment, this approach allows systematic investigation of fundamental biological processes by applying recent advances in micro/nanofabrication techniques to engineer the cellular environment.

9417-98, Session PSWed

Investigating the geometry of pig airways using computed tomography

Hansen Mansy, Khushid Azad, Brandon McMurray, Univ. of Central Florida (United States); Brian Henry, Thomas Royston, Univ of Illinois at Chicago (United States); Richard Sandler, Nemours Chirldren's Hospital (United States)

Numerical modeling of sound propagation in the airways requires accurate knowledge of the airway geometry. These models are often validated using animal experiments. Many studies documented the geometric details of the human airways. However, information about the geometry of pig airways is more scarce. In addition, the morphology of animal airways can be significantly different from that of humans. The objective of this study is to measure the airway diameter, length and bifurcation angles in

domestic pigs using computed tomography. After imaging the chest of 3 pigs, segmentation software tools were used to extract the geometry of the airway lumen. The airway dimensions were then measured from the resulting 3 D models for the first 10 airway generations. The measured airway dimensions were compared with those of the human airways. Results showed that the size and morphology of the airways of different animals were similar. The trachea diameter was found to be comparable to the adult human size. However, the diameter, length and branching angles of other airways were found significantly different from that of humans. For example, pigs consistently had an early airway branching from the trachea that precedes the main carina and feeds the top right lung lobe. This branch is absent in the human airways. These results suggested that the human geometry may not be a good approximation of the pig airways and may contribute to increasing the errors when the human airway geometric values are used in computational models of the pig chest.

9417-99, Session PSWed

Three-dimensional segmentation of pulmonary artery volume from thoracic computed tomography imaging

Tamas J. Lindenmaier, Robarts Research Institute (Canada) and The Univ. of Western Ontario (Canada); Khadija Sheikh, Robarts Research Institute (Canada) and Medical Biophysics, The University of Western Ontario (Canada); Emma Bluemke, Igor Gyacskov, Robarts Research Institute (Canada); Marco Mura, Christopher Licskai, The Univ. of Western Ontario (Canada); Lisa Mielniczuk, Univ. of Ottawa Heart Institute (Canada); Aaron Fenster, Ian A. Cunningham, Grace Parraga, Robarts Research Institute (Canada) and The Univ. of Western Ontario (Canada)

Chronic obstructive pulmonary disease (COPD), is the major contributor to yearly hospitalization and healthcare costs in North America. In addition to progressively worsening airflow limitation, COPD is concomitant with abnormalities of the cardiovascular system including the pulmonary arteries (PA). COPD patients commonly develop pulmonary hypertension, which is linked to an enlarged PA. While previous studies have utilized a one-dimensional diameter measurement to assess changes in the size of the main PA, a more specific, three-dimensional (3D) technique could be more suitable for quantifying and tracking changes in PA size, as it would encompass morphological changes of the vessel. We sought to develop a 3D measurement for quantifying the size of the main (MPA), left (LPA) and right (RPA) pulmonary arteries from thoracic CT volumes. The segmentation technique incorporates segmentation of pulmonary vessels in cross-section for the MPA, LPA and RPA to provide an estimate of their volumes over a proscribed region of interest. Two observers performed five repeated measurements of 15 ex-smokers randomly identified from a larger dataset of 200 patients, all with a smoking history of ≥10 pack years. There was a strong agreement (r2=0.76) for PA volume and PA diameter measurements, which we used as a gold standard. The coefficients of variation for repeated measurements of Observer 1 and Observer 2 were MPA: 2.13%, LPA: 2.53%, RPA: 1.93% and MPA: 8.14%, LPA: 4.88%, RPA: 5.37% respectively and the measurements for each observer were strongly correlated.

9417-101, Session PSWed

Microstructure analysis of the pulmonary acinus using a synchrotron radiation CT

Yoshitaka Tokumoto, Koichi Minami, Yoshiki Kawata, Noboru Niki, Univ. of Tokushima (Japan); Keiji Umetani, Japan Synchrotron Radiation Research Institute (Japan); Yasutaka Nakano, Shiga Univ. of Medical Science (Japan); Hiroaki Sakai, Hyogo Prefectural Amagasaki Hospital (Japan); Hironobu Ohmatsu, National Cancer Ctr. Hospital East (Japan); Harumi Itoh, Univ. of Fukui (Japan)

Conversion of images at micro level of the normal lung, those with very early stage lung disease and the quantitative analysis of morphology on the images can contribute to the chest image diagnosis in the next generation. The collection of high-resolution CT images at micro level is necessary in using high luminance synchrotron radiation CT for converting the images. The purpose of this study is to analyze the structure of secondary pulmonary lobule of the lung. We also show the structure of the pulmonary acinus by means of extending our vision to a wider field through the image reconfiguration from the projection image of synchrotron radiation CT.

9417-102, Session PSWed

Building a bone microCT images atlas for micro-architecture recognition

Erwan Freuchet, Univ. de Nantes (France); Benoit Recur, Andrew M. Kingston, The Australian National Univ. (Australia); Jean-Pierre V. Guédon, Univ. de Nantes (France); Yves Amouriq, Univ. of Nantes, Odontology (France)

Trabecular bone and its micro-architecture are of prime importance for health. Micro-CT is a good way to characterize trabecular bone and allows to compute a set a parameters. In this paper, we present the building of an atlas of 3D microCT bone volumes of rats based on a few acquired samples. From these samples, we computed hundreds of volumes using simple primitives of discrete geometry (mathematical morphology). Each of these new computed volume has to be visually consistent (otherwise rejected). Each volume is then represented by a set of 2D and 3D parameters characterizing the bone as TB/TV, the bone thickness and the bone separation or its fractal dimension. Finally, we checked if the composition of our atlas allows for two main principles: 1) the Atlas fulfills the set of parameters; 2) we are able to retrieve a volume from the Atlas which exhibits the shortest distance with any given set of parameters.

9417-103, Session PSWed

Bone vascularization and bone micro-architecture characterizations according to the microCT resolution

Eleonore Crauste, Florent Autrusseau, Jean-Pierre V. Guédon, Paul Pilet, Univ. de Nantes (France); Yves Amouriq, Univ. of Nantes (France); Pierre Weiss, Univ. de Nantes (France); Bernard Giumelli, Univ. of Nantes (France)

Trabecular bone and its microarchitecture are of prime importance for health. Studying vascularization helps to better know the relationship between bone and vascular microarchitecture. This research uses an animal study (ten rats), based on the perfusion of vascularization by a contrast agent (a mixture of 50% barium sulfate with 1.5% of gelatin) before euthanasia. The samples (mandibular and legs) were studied by microCT at different resolutions ranging from 18 to 6μm. Softwares (NRecon Reconstruction, CtAn, and ImageJ)were used to calculate bone and vessels microarchitecture parameters. This study aims to determine the variations of the most important parameters according to the microCT resolution. The first results show that the values of the main characteristics both for bone and for vessels are changing according to the acquisition resolution. We get results which seems to be in accordance with a simple psychovisual experiment made to correlate what specialists are detecting onto the images and the values of the main characteristics. Even if the vessels area seems to be stable, their detected number increases when the pixel resolution also increases. The fractal dimension of the vessels tends to one

(no fractal behavior) while it increases with the resolution for trabecular bone.

9417-107, Session PSWed

Pharmacokinetic characterization of tumor treatment response

Jonathan M. Martin, Arizona State Univ. (United States); Praveen K. Gulaka, The Univ. of Texas Southwestern Medical Ctr. at Dallas (United States); Vikram D. Kodibagkar, Arizona State Univ. (United States)

The objective of the research presented here was the use of a first-order kinetic model to determine changes in pharmacokinetic properties, in particular permeability and the vascular fraction in treated tumors, from data acquired with a dynamic contrast enhanced magnetic resonance imaging (DCE-MRI) procedure. Rats were implanted with syngeneic MTLN3 breast tumors, imaged using a DCE-MRI procedure on day 0, and subsequently treated with daily metronomic schedule of cyclophosphamide. The DCE-MRI procedure was repeated for each rat on day 7. The results indicated that the tumors responded to the treatment (decrease in size), and there was a statistically significant increase in the parameters of the pharmacokinetic model that correspond to permeability of the tissue (Ktrans) and the presence of viable local vasculature in the tissue (vp). These parameters were also seen to have a more homogenous distribution across the tumor after low-dose metronomic chemotherapy, compared to pre-treatment data. These data suggest that pharmacokinetic analysis of DCE-MRI data may have diagnostic value, quantifying changes in tumor vasculature, noninvasively, throughout the course of a treatment regimen.

9417-108, Session PSWed

Use of scanning probe microscopy for study of paraneoplastic changes in red blood cells in carcinogenesis dynamics

Tatyana Gening, Boris Kostishko, Antonina Tuzeeva, Dinara R. Dolgova, Inna Antoneeva, Tatyana Abakumova, Ekaterina Pchelintseva, Ulyanovsk State Univ. (Russian Federation); Anastasiya Fomina, Department of physiology and pathophysiology of Ulyanovsk State University (Russian Federation)

The scanning probe microscopy methods used in the present study revealed that carcinogenesis and character of malignant process determine state of biochemical homeostasis. It is shown that malignant tumors can affect blood system, in particular, can change erythrocyte morphofunctional parameters. Scanning probe microscopy method allowed to study the parameters of cells without their long term fixing, thereby ensuring more reliable data. Thus, the local elastic properties of cell membranes have been estimated (evaluated). The cell topology and membrane rigidity have been studied to reveal SPM applicability for estimation of paraneoplastic changes observed in red blood cells in carcinogenesis dynamics of patients with ovarian cancer (FIGO I-IV stage) and tumor-bearing animals with experimental ovarian cancer. The following parameters of redox-dependent processes have been determined in erythrocyte hemolysate: the level of diene conjugates, ketodienes, Schiff bases, the activity of glutathione-transferase, catalase and superoxide dismutase as well as the ratio of reduced to oxidized glutathione (GSH / GSSG). Mathematical analysis demonstrates dependence of the studied parameters of paraneoplastic changes in red blood cells on malignant process stage.

9417-109, Session PSWed

Endoscopic Cerenkov luminescence imaging: in vivo small animal tumor model validation

Tianming Song, Chengpeng Bao, Harbin Univ. of Science and Technology (China); Zhenhua Hu, Kun Wang, Institute of Automation (China); Xia Liu, Harbin Univ. of Science and Technology (China); Jie Tian, Institute of Automation (China)

Background

Cerenkov luminescence imaging (CLI) provides a great potential for clinical translation of optical molecular imaging techniques through using clinical approved radiotracers. However, it is difficult to obtain the Cerenkov luminescence signal of deeper biological tissues due to the small magnitude of the signal. To efficiently acquire the weak Cerenkov luminescence, we developed an endoscopic Cerenkov luminescence imaging (ECLI) system to improve the in vivo imaging depth with minimum invasion, and validated the system on small animal tumor models.

Methods

For the ECLI system, the laparoscope was connected to a high sensitive charge-couple device (CCD) camera (DU888+, Andor, UK) by a custom made adapter. We conducted a series of in vitro and in vivo experiments by use of the system. In the in vitro experiment, the endoscopic luminescence images of the 18F-FDG with various activities in EP tubes were acquired using ECLI system, and the sensitivity was compared with conventional CLI system. In the in vivo tumor experiment, 18F-FDG with the activity of 50 ?Ci were intravenously injected into 3 tumor mice, and the PET scan was performed 30 minutes later. Then the ECLI system was used to acquire the optical images for both non-invasive and invasive conditions.

Results

The preliminary results of the in vitro experiment showed that ECLI system could detect Cerenkov light emitted from 1 ?Ci 18F-FDG. The in vivo tumor experiment results indicated that ECLI can acquire the Cerenkov signals from tumor tissues with minimum invasion.

Conclusions

Experimental data showed the ECLI system could detect the 18F-FDG with the activity as low as 1?Ci. Furthermore, our preliminary results indicated the possibility of ECLI technique for detecting Cerenkov signals inside the tumor tissue with deeper depth. We believe that this technique can help to accelerate the clinical translation of CLI.

9417-111, Session PSWed

Size based emphysema cluster analysis on low attenuation area in 3D volumetric CT: comparison with pulmonary functional test

Minho Lee, Namkug Kim, Sang Min Lee, Joon Beom Seo, Sang Young Oh, Univ. of Ulsan, Asan Medical Ctr. (Korea, Republic of)

To quantify low attenuation area (LAA) of emphysematous regions according to cluster size in 3D volumetric CT data of chronic obstructive pulmonary disease (COPD) patients and to compare these indices with their pulmonary functional test (PFT). Sixty patients with COPD were scanned by a more than 16-multi detector row CT scanner (Siemens Sensation 16 and 64) within 0.75mm collimation. Based on these LAA masks, a length scale analysis to estimate each emphysema LAA's size was performed as follows. At first, Gaussian low pass filter from 30mm to 1mm kernel size with 1mm interval on the mask was performed from large to small size, iteratively. Centroid voxels resistant to the each filter were selected and dilated by the size of the kernel, which was regarded as the specific size emphysema mask. The power law Ds of area and number of size based LAA (slope of log-log

plot) were analyzed and compared with PFT.

PFT parameters including DLco, FEV1, and FEV1/FVC were significantly (all p-value < 0.002) correlated with the power law D (r-values; -0.73, 0.54, 0.69, respectively) and EI (r-values; -0.84, -0.60, -0.68, respectively). In addition, the D independently contributed regression for FEV1 and FEV1/FVC (adjust R sq. of regression study: EI only, 0.70, 0.45; EI and D, 0.71, 0.51, respectively).

By the size based LAA segmentation and analysis, we evaluated the Ds of area, number, and distribution of size based LAA, which would be independent factors for predictor of PFT parameters.

Conference 9418: PACS and Imaging Informatics: Next Generation and Innovations

Sunday - Monday 22–23 February 2015

Part of Proceedings of SPIE Vol. 9418 Medical Imaging 2015: PACS and Imaging Informatics: Next Generation and Innovations

9418-1, Session 1

Practical applications and pitfalls of 'big data' for decision support in medical imaging and informatics *(Keynote Presentation)*

Eliot L. Siegel, Univ. of Maryland Medical Ctr. (United States)

'BIG DATA' is currently one of the hottest topics in medicine from a research and clinical perspective. However, it's impossible to get any consensus on its definition. IBM and others have defined it in terms of the four V's, volume, velocity, variety, and, particularly relevant to healthcare, veracity

Whichever definition that we may use when thinking of "Big Data", medicine and in specific, diagnostic imaging clearly generates vast amounts of it. The volume and complexity of medical information in healthcare has doubled every five years with 80% or more of that data unstructured.

One of the major challenges with medical imaging is the difficulty of discovery of imaging information in the electronic medical record and from clinical trial data. Our imaging reports are, almost without exception, unstructured and our medical images are rarely tagged in such a way as to be discoverable or useful to data mining efforts. This must change if medical imaging is to play a substantial role in this era of big data, medical guidelines, decision support and personalized medicine.

The goals of this presentation include defining "Big Data" and issues such as archival of clinical images and other data and metadata, exploring the current role and applications of big data in diagnostic imaging with an emphasis on clinical applications and speculating about the potential and future applications of Big Data to help in visualization of images and data, and diagnosis and treatment. Practical applications for decision support and screening will be presented.

9418-2, Session 1

Big data issues in medical imaging informatics

Jianguo Zhang, Shanghai Institute of Technical Physics (China)

Purpose:

Medical imaging services and research generates big data, not only because of the sheer volume of information, but also due to the complexity, diversity, and the rich context of the data that encompasses imaging discoveries of structures and functions from molecular levels to organ levels with large-?scale population studies on determinants of health status. Comparing to big data of other areas such as social networking, e-commercial and manufactures, there are some special challenges to deal with the big data in medical imaging to discover more values for clinical services and research. In this presentation, we will brief some key technical issues of big data in medical imaging informatics.

Method and Materials:

Typical big data has four V features such as Volume, Veracity, Variety and Velocity. These four V features have special characters in big data of medical imaging informatics. The Volume in medical imaging is very obvious as most large hospitals (≥1000 beds) or regional healthcare enterprises can easily generate 50-100 TB images per year. The Veracity in medical image mostly are caused by difference between modality types, scanning protocols, as well as judging difference between radiologists. The Variety

in medical imaging are very straight forward as the same organ/body part can be scanned by different modalities and generated multiple of data types with different information of the structure, function and pathology of the organ/body part, also, same image such as a 3D lung CT data set or a brain MR data set can be displayed or visualized with different display modes (MPR, MIP, VR, SSD) with different display parameters. The Velocity in medical imaging means that the data processing from acquisition, communication, storage to applications in intranet of enterprise healthcare or wide are network healthcare applications needs high throughput solution if large volume of data set is considered, especially in cloud or mobile based applications. These four V features of big data in medical imaging informatics lead the clinical challenges facing in radiology and other medical imaging applications such as in use of medical image to perform diagnosis, computerized to discover more value information from medical image data, as well as content-based image retrieval from PACS.

Results:

Comparing to big data issues of other areas such as social networking, e-commercial and manufactures, issues of big data in medical imaging informatics has special characters which needs to be deal with in healthcare service and research. These characters lead to four major technical challenges in medical imaging informatics such as requiring better methods of disease pattern recognition in medical images, quantitative imaging related technical problems, consistent express and content-based index methods for variety kinds of medical images, and high performance imaging computing platform for healthcare services. Possible and perspective solutions of these challenges are discussed.

New Technologies and Results to be Presented:

The particle sizes and hiding states of medical imaging are major factors which make big data of medical imaging be quite different from other kind of big data.

Conclusions:

The issues of big data in medical imaging informatics has special characters which needs to be deal with in healthcare service and research. These characters lead to four major technical challenges in medical imaging informatics. The particle sizes and hiding states of medical imaging are major factors which make big data of medical imaging be quite different from other kind of big data. The possible and perspective solutions of big data issues in medical imaging informatics are discussed in this presentation.

9418-3, Session 2

Review of clinical documentation and data storage systems: a must and burden - Prospects on future use of big data for analyses in radiation oncology

Kerstin A. Kessel, Stephanie E. Combs, Technische Univ. München (Germany)

Recently, information availability has become more elaborate and wide spread, and treatment decisions are based on a multitude of factors including imaging, molecular or pathological markers, surgical results and patient's preference. In this context the term 'big data' evolved also in health care. The 'hype' is heavily discussed in literature, and how to use the valuable information in patient care. Radiooncology is a highly image intensive medical specialty. Not only a heterogeneous and voluminous amount of data must be evaluated, it is also spread in different styles across various information systems. Exactly this concept is also referred to in many ongoing discussions about big data - the 'three V's': volume, velocity, and variety. We reviewed 892 articles extracted from PubMed about current

developments in electronic clinical data management systems and their further analysis or post-processing procedures. Few articles show first ideas and ways to immediately make use of collected data, particularly imaging data. Many developments can be noticed in the field of clinical trial or analysis documentation, mobile devices for documentation, and genomics research. Using big data to advance medical research is definitely on the rise. Health care is perhaps the most comprehensive, important and economically viable field of application.

9418-4, Session 2

What makes 'Big data' different from 'regular data' within Radiology? The easiest answer; When it no longer fits into Excel!

Lars Lindsköld, Västra Götaland (Sweden) and Karolinska Institutet (Sweden); G. Alvfeldt, Karolinska Institutet (Sweden) and SLL (Sweden); Mikael Wintell, Västra Götaland (Sweden)

Challenges of today's healthcare is that data from radiology is heterogeneous and stored in silos created by PACS vendors. Also seen is a lack of harmonized information-models as well as healthcare standards in use.

Radiology in Region Västra Götaland has been entering the "Big Data world" since 2006, by using information technology that is without doubt the strongest force of structural changes we see in healthcare today, 34 departments using the same information infrastructure (8 different PACS DB). As an organization building for the future we must meet the values and requirements of the stakeholders.

Can" Big Data" be a valuable asset from a regional management perspective?

Our initial findings indicates that this is the case, based on three different perspectives – work practice changes, understanding data quality when sharing information and introducing new services in work practice. Going from local to enterprise workflow utilizing the power of "Big Data" not only by volume but combining diverse sources to aggregate the information domains visualize new trends as well as dependencies more effectively. Building trust by the use of Big Data in healthcare involves a long and winding journey, but the persevering infrastructure-oriented organization will give new ways of collaboration. It also involves continuous negotiation with people concerning how and why they should collaborate with new actors within the region to achieve patient centric care. This will nurture a more open-minded, hopeful and life-affirming holistic approach involving all stakeholders, newcomers' specialists and patients.

The lessons learned by means of" Big Data" be a valuable asset from a regional management perspective?

9418-5, Session 2

Interactive analysis of geographically distributed population imaging data collections over light-path data networks

Baldur van Lew, Leiden Univ. Medical Ctr. (Netherlands); Charl P. Botha, vxlabs (Pty) Ltd. (South Africa); Julien R. Milles, Philips Healthcare (Netherlands); Henri A. Vrooman, Erasmus MC (Netherlands); Martijn van de Giessen, Boudewijn P. F. Lelieveldt, Leiden Univ. Medical Ctr. (Netherlands)

Epidemiological studies involving combined imaging and –omics data often suffer from the "curse of dimensionality" and are often statistically underpowered. This can be addressed by aggregating data from multiple institutions. However, hospital data is subject to strict privacy and data protection regimes. Following local legal constraints, data must often be physically stored within the hospital / research organization, and cannot be transferred to external repositories beyond the control of the data provider. In addition interactive data exploration requires high-bandwidth, low latency access to the data. Light-path data networks address both issues by providing fast and inherently secure connections. Combining light-paths with a central secure cloud computing framework we aimed to create a data communication and computing resource to enable interactive, compute intensive exploration of geographically distributed, privacy sensitive medical data collections. The availability of a star-shaped light-path network between medical centers and the central compute node provides high-speed and low-latency for responsive interactive data exploration (<1ms ping times between network endpoints). Data disks are physically located in medical centers, and mounted over light-paths to the central compute node, obviating the need for centralized, external data storage. Additionally, we developed an interactive data exploration framework with processing pipelines, interactive analysis and job scheduling. A neuro-imaging data analysis use case was processed, and results accessed via a web-API. The effectiveness of the presented framework proves that it can form an important tool for collaborative clinical research supplying statistical and computing power while maintaining data security, high transfer rates and low interaction latency.

9418-6, Session 2

Towards secondary use of heterogeneous radio-oncological data for retrospective clinical trials: Service-oriented connection of a central research database with image analysis tools

Nina Bougatf, UniversitätsKlinikum Heidelberg (Germany) and German Cancer Research Ctr. (Germany); Rolf Bendl, Deutsches Krebsforschungszentrum (Germany) and Hochschule Heilbronn (Germany); Jürgen Debus, UniversitätsKlinikum Heidelberg (Germany)

Our overall objective is the utilization of heterogeneous and distributed radio-oncological data in retrospective clinical trials. Previously, we have successfully introduced a central research database for collection of heterogeneous data from distributed systems. The next step is the integration of image analysis tools in the standard retrieval process. Hence, analyses for complex medical questions can be processed automatically and facilitated immensely. In radiation oncology recurrence analysis is a central approach for the evaluation of therapeutic concepts. However, various analysis steps have to be performed like image registration, dose transformation and dose statistics. In this paper we show the integration of analysis tools in the standard retrieval process by connecting them with our research database using a service-oriented approach. A concrete problem from recurrence analysis has been selected to prove our concept exemplarily. We implemented service-oriented data collection and analysis tools to use them in a central analysis platform, which is based on a workflow management system. An analysis workflow has been designed that, at first, identifies patients in the research database fulfilling the inclusion criteria. Then the relevant imaging data is collected. Finally the imaging data is automatically analyzed. After the successful workflow execution, the results are available for further evaluation by a physician. As a result, the central research database has been connected successfully with automatic data collection and image analysis tools and the feasibility of our service-oriented approach has been demonstrated. In conclusion, our approach will simplify retrospective clinical trials in our department in future.

9418-7, Session 2

Visualizing and representing trends in research fields' dynamics such as medical imaging

Philippe F. Journeau, ResearXis, Inc. (United States)

Visualizing and Representing trends in Research fields' dynamics such as Medical Imaging

This paper presents progress on imaging the research field of Imaging Informatics, mapped as the clustering of its communities together with their main results by applying a process to produce a dynamical image of the interactions between their results and their common object(s) of research.

The basic side draws from a fundamental research on the concept of dimensions and projective space spanning several streams of research about three-dimensional perceptivity and re-cognition and on their relation and reduction to spatial dimensionality.

The application results in an N-dimensional mapping in Bio-Medical Imaging, with dimensions such as inflammatory activity, MRI acquisition sequencing, spatial resolution (voxel size), spatiotemporal dimension inferred, toxicity, depth penetration, sensitivity, temporal resolution, wave length, imaging duration, etc.

Each field is represented through the projection of papers' and projects' 'discriminating' quantitative results onto the specific N-dimensional hypercube of relevant measurement axes, such as listed above and before reduction. Past published differentiating results are represented as red stars, achieved unpublished results as purple spots and projects at diverse progress advancement levels as blue pie slices. The goal of the mapping is to show the dynamics of the trajectories of the field in its own experimental frame and their direction, speed and other characteristics.

We conclude with an invitation to participate and show a sample mapping of the dynamics of the community and a tentative predictive model from community contribution.

9418-40, Session 2

Big data in multiple sclerosis: development of a web-based longitudinal study viewer in an imaging informatics-based eFolder system for complex data analysis and management

Kevin C. Ma, Ximing Wang, Alex Lerner, Mark Shiroishi, Lilyana Amezcua, Alexander Tarashansky, Brent J. Liu, The Univ. of Southern California (United States)

In the past, we have developed and displayed a multiple sclerosis eFolder system for patient data storage, image viewing, and automatic lesion quantification results stored in DICOM-SR format. The web-based system aims to be integrated in DICOM-compliant clinical and research environments to aid clinicians in patient treatments and disease tracking. This year, we have further developed the eFolder system to handle big data analysis and data mining in today's medical imaging field. The database has been updated to allow data mining and data look-up from DICOM-SR lesion analysis contents. Longitudinal studies are tracked, and any changes in lesion volumes and brain parenchyma volumes are calculated and shown on the web-based user interface as graphical representations. Longitudinal lesion characteristic changes are compared with patients' disease history, including treatments, symptom progressions, and any other changes in the disease profile. The image viewer is updated such that imaging studies can be viewed side-by-side to allow visual comparisons. We aim to use the web-based medical imaging informatics eFolder system to demonstrate big data analysis in medical imaging, and use the analysis results to predict MS disease trends and patterns in Hispanic and Caucasian populations in our pilot study. The discovery of disease patterns among the two ethnicities is a big data analysis result that will help lead to personalized patient care and treatment planning.

9418-8, Session 3

Web-based PACS and EHR system

Ashesh Parikh, Nihal Mehta, netDICOM (United States)

A barrier to efficiently using EHR systems by healthcare professionals is the difficulty in obtaining patient records from multiple institutions and combining with PACS to form a comprehensive view of a patient's health status.

A web-based, integrated system is described that allows patient records that include patient's medical history, diagnoses, treatment plans, radiology images and laboratory results. Digital images, in particular, form a significant input for diagnosing a patient's health state, are difficult to examine on an integrated viewer because of their custom formats. Integrating them across institutions is even more challenging (e.g. CAT scan at Hospital A, chest x-ray at hospital B, etc.). We demonstrate how some of the newer internet standards (HTML5) combined with a database driven architecture over the cloud can eliminate many of the issues and allow the display of all types of images (DICOM, NIfTI, JPEGs, etc.), regardless of modality, on a standard web browser with zero footprint achieving one of the goals of IHE.

This architecture also offers the ability to securely exchange information to other systems using standard protocols (SOAP, XML, etc.). This mechanism greatly simplifies sharing of information securely amongst institutions regardless of the system implementation of each institution. As a result, a virtual EHR dashboard that seamlessly combines information (including the non-standard radiology and digital images) can be presented to healthcare professionals without them having to individually access a patient's EHR from multiple institutions. As will be illustrated, this approach goes a long way towards achieving a Vendor Neutral Archive (VNA).

9418-9, Session 3

Web-based platform for collaborative medical imaging research

Leticia Rittner, Mariana P. Bento, André L. Costa, Roberto M. Souza, Rubens C. Machado, Roberto A. Lotufo, Univ. Estadual de Campinas (Brazil)

Medical imaging research depends basically on the availability of large image collections, image processing and analysis algorithms, hardware and a multidisciplinary research team. It has to be reproducible, free of errors, fast, accessible through a large variety of devices spread around research centers and conducted simultaneously by a multidisciplinary team. Therefore, we propose a collaborative research environment, where tools and dataset are integrated and readily available in the Internet through a web browser. Moreover, processing history and all intermediate results are stored and displayed in automatic generated web pages for each object in the clinical study. It requires no installation or configuration from the client side and offers centralized tools and specialized hardware resources, since processing takes place in the cloud.

9418-10, Session 3

On-line scalable image access for medical remote collaborative meetings

Sebastian R. Tarando, Télécom SudParis (France); Olivier Lucidarme, Philippe A. Grenier, Pitié-Salpêtrière Hospital (France); Catalin Fetita, Télécom SudParis (France)

The increasing need of remote medical investigation services in the framework of collaborative multidisciplinary meetings (e.g. cancer follow-up) raises the challenge of on-line remote access of (large amount of) radiologic data in a limited period of time. This paper proposes a scalable compression framework of DICOM images providing low-latency display through low speed networks. The developed approach relies on useless

information removal from images (i.e. not related with the patient body) and the exploitation of the JPEG2000 standard to achieve progressive quality encoding and access of the data. This mechanism also allows the efficient exploitation of any idle times (corresponding to on-line visual image analysis) to download the remaining data at lossless quality in a way transparent to the user, thus minimizing the perceived latency. The experiments performed in comparison with exchanging uncompressed or JPEG-lossless compressed DICOM data, showed the benefit of the proposed approach for collaborative on-line remote diagnosis and follow-up services.

9418-11, Session 3

Integrating research and clinical neuroimaging for the evaluation of traumatic brain injury recovery

Justin Senseney, John M. Ollinger, John Graner, Wei Lui, Terry Oakes, Gerard Riedy, National Intrepid Ctr. of Excellence (United States)

Advanced MRI research and other imaging modalities may serve as biomarkers for the evaluation of traumatic brain injury recovery. However, these advanced modalities require off-line processing which creates images that are incompatible with radiologist viewing software sold commercially. AGFA Impax is an example of such a PACS system that is used throughout the Military Health System in the United States. By taking advantage of Impax's use of the Digital Imaging and Communications in Medicine (DICOM) standard, we developed a system that allows for advanced medical imaging to be incorporated into clinical PACS. Radiology research can now be conducted using existing resources in combination with image processing techniques that are only available outside of the clinical scanning environment. We extracted the spatial and identification elements of the DICOM standard that are necessary to allow research images to be incorporated into a clinical radiology system, and developed a tool that annotates research images with these tags. This allows for the evaluation of imaging representations of biological markers that may be useful in the evaluation of TBI and TBI recovery.

9418-12, Session 3

Characterizing stroke lesions using digital templates and computer-aided lesion quantification tools in a web-based imaging informatics system for a large-scale stroke rehabilitation clinical trial

Ximing Wang, The Univ. of Southern California (United States); Matthew Edwardson, National Institutes of Health (United States); Alexander Dromerick, MedStar National Rehabilitation Network (United States); Carolee J. Winstein, Jing Wang, Brent J. Liu, The Univ. of Southern California (United States)

Previously, we presented the Interdisciplinary Comprehensive Arm Rehabilitation Evaluation (ICARE) imaging informatics system: an imaging informatics-based electronic patient record (ePR) that supports a large-scale phase III stroke rehabilitation trial. The ePR system is capable of displaying anonymized patient imaging studies and reports, and the system is accessible to clinical trial sites and users across the United States via the web. However, prior multicenter stroke rehabilitation trials lack any significant neuroimaging analysis infrastructure. This is mostly due to the difficulty in big data handling and developing a uniform method to analyze scans of varying modality, acquisition settings, quality, and time point after stroke. By overcoming these challenges, we hope to gain insight into specific lesion characteristics, such as vascular territory, for patients enrolled into large stroke rehabilitation trials. To enhance the system's capability

for data analysis and data reporting, we have added three new features: a digital brain template display, a semi-automatic lesion quantification tool, and a digital case report form. The new, integrated system features provide the user with readily-accessible web-based tools to identify the vascular territory involved, calculate 3D lesion volume, and store these results in a web-based digital format.

The digital brain templates are compiled from published vascular territory templates at each of 5 angles of incidence. These templates were updated to include territories in the brainstem using a vascular territory atlas and the Medical Image Processing, Analysis and Visualization (MIPAV) tool. The digital templates are displayed for side-by-side comparisons and transparent template overlay onto patients' images in the image viewer. The semi-automatic lesion quantification tool quantifies 3D stroke lesion volume from user-defined end points. The digital case report form stores user input into a database, then displays contents in the interface to allow for reviewing, editing, and new inputs. The integrated web-based system was optimized using feedback from stroke and rehabilitation physicians. The features are now complete and integrated within the overall ICARE imaging informatics system. Each feature has been evaluated by users to perform data viewing, data input, and lesion volume and location analysis.

9418-13, Session 4

PACS on mobile devices

Ashesh Parikh, Nihal Mehta, netDICOM (United States)

The biggest shift in technology driven by growth and power of mobile devices and speedier networks has enhanced the human lifestyle and experience by applications that are more creative in design. This offers an opportunity for healthcare professionals to effectively synthesize information from a variety of sources to enhance patient treatment. Here, a cloud-based system that can handle medical images (DICOM's/NIfTI) using a standard web-browser on a user's device such as Apple's iPad, desktop computers and smartphones is described. The system is modular with specific modules designed to enable specific tasks such as controlled user access, image acquisition, viewing, processing and rendering. Specifically, the viewer module employs a hybrid approach of using server-side code and client-side code (HTML and Javascript) that together enable the display of non-native images on the user's web browser with zero footprint. The role of the server-side code is to obtain the individual bits of the image file and send them down to the user's web browser. The client-side code contains the specific instructions on interpreting the organization of the bytes in the image file. The advantage of using web-based technology is that it makes available to the user all the standard capabilities such as notifications, reminders, auditing, meta data annotations, combining meta data from one image with another, auto-detection of meta data changes and alert notifications without human intervention. Finally, besides viewing information available in the medical images, they can also be stored for auditing and billing purposes.

9418-14, Session 4

PACS: next generation

Ashesh Parikh, Nihal Mehta, netDICOM (United States)

Next generation of PACS should provide the ability to transfer images reliably, securely and quickly over a network together with the ability to view them without time delay even for large images over the cloud. Typical PACS over LAN were not designed for streaming multi-media images and video. On the other hand, a cloud based architecture using standard protocols (streaming, SOAP, etc.) can leverage widely available infrastructure. Specifically, large images can be automatically broken-up on the server and streamed over the network to the user. Unlike CAD viewers, streaming images and video to view on a web browser can be made with standard technology thereby delivering a superior user experience. Here a zero footprint viewer that can meet all these requirements, without plugins and without the user having to explicitly unzip/uncompress images is demonstrated. This architecture naturally lends itself to secure

communications over the cloud without the need for costly VPN.

PACS as it stands today is primarily a "pull" model in which an explicit request for viewing images is made by healthcare professionals. A web-based architecture, offers the ability to embrace a "push" model that can automatically send alerts to patient care providers when new information indicates ab- normalities, something that cannot be easily achieved with traditional LAN architectures.

The path to perform additional tasks such as image segmentation, process-ing, 3D renderings, etc. that require CAD based systems, on web browsers is also illustrated here.

9418-15, Session 4

Web-based 3D digital pathology framework for large-mapping data scanned by FFOCT

ChiaKai Chang, Chien-Chung K. Tsai, Meng-Ting Chien, National Taiwan Univ. (Taiwan); Yu-I Li, Chia-Tung Shun, National Taiwan Univ. College of Medicine (Taiwan); Sheng-Lung L. Huang, National Taiwan Univ. (Taiwan)

We have set up a Full Field OCT (FFOCT) scanning instrument that can be performed cellular resolution tomography scanning for skin tissue or histopathology. In (1cm, 1cm, 200μm) (xyz) scan range, for example, digital data accounted for 295 GB capacity. Copying these materials is very difficult, not to mention efficiently browsing and analyzing these data. To solve the problem of information delivery, we have established a network service to analyze the huge volume data.

We propose a framework to analysis and present large volume data, looking forward to applying this framework to 3D digital pathology. In our framework, during the controlling computer of FFOCT instrument performing FFOCT scan, client control program will perform 3D stitching and automatically select several en-face for different depth. After finishing FFOCT scanning, several large, different depth en-face images will be uploaded to server. Then, the several tile of these images can be presented as a map in front end web interface.

We designed a rich web interface using JavaScript. Users can search, browse, note, analysis, drag, zoom in/out, and switch between different depth and allow users to define mathematical data processing script via web browsers.

9418-16, Session 4

Volumetric MRI visualisation through digitally reconstructed radiographs

Antoine Serrurier, Andrea Boensch, RWTH Aachen Univ. (Germany); Robert Lau, Uniklinik RWTH Aachen (Germany); Thomas M. Deserno, RWTH Aachen Univ. (Germany)

Visualising volumetric medical images such as Computer Tomography (CT) and Magnetic Resonance Imaging (MRI) on PACS clients is often achieved by image browsing in sagittal, coronal or axial views or three-dimensional (3D) rendering. This latter technique requires however fine threshold adaptation for MRI. On the other hand, computing virtual radiograph images, also referred to as Digitally Reconstructed Radiographs (DRR), provides in one bidimensional image an overview of the 3D dataset and appears therefore as a powerful alternative for MRI visualisation. This study describes a method to compute DRR from T1-weighted MRI. After segmentation of the background, an histogram distribution analysis is performed and each foreground MRI voxel is labelled as one of three tissues: cortical bone, also known as principal absorber of the X-rays, muscle and fat. An intensity level is attributed to each voxel according to the Hounsfield scale, linearly related to the X-ray attenuation coefficient. Each DRR pixel is computed

as the accumulation of the new intensities of the MRI dataset along the corresponding X-ray. The method has been tested on 10 T1-weighted MRI datasets. Frontal and lateral DRR have been computed with reasonable qualities and approach literature results based on image segmentations. Further work is required to validate and extend these proof-of-concept results in order to be useable for PACS clients.

9418-17, Session 4

OpenID Connect as a Security Service in Cloud-based Diagnostic Imaging Systems

Weina Ma, Kamran Sartipi, Hassan Sharghi, Univ. of Ontario Institute of Technology (Canada); David A Koff, McMaster Univ. (Canada); Peter R.G. Bak, MIIRC@M (Canada)

The evolution of cloud computing is driving the next generation of diagnostic imaging (DI) systems. Cloud-based DI systems are able to deliver better services to patients without constraining to their own physical facilities. However, privacy and security concerns have been consistently regarded as the major obstacle for adoption of cloud computing by healthcare domains. Furthermore, traditional computing models and interfaces employed by DI systems are not ready for accessing diagnostic images through mobile devices. RESTful is an ideal technology for provisioning both mobile services and cloud computing. OpenID Connect, combining OpenID and OAuth together, is an emerging REST-based federated identity solution. It is one of the most perspective open standards to potentially become the de-facto standard for securing cloud computing and mobile applications, which has ever been regarded as "Kerberos of Cloud". We introduce OpenID Connect as an authentication and authorization service in cloud-based DI systems and propose enhancements that allow for incorporating this technology within distributed enterprise environment. The objective of this study is to offer solutions for secure radiology image sharing among DI-r (Diagnostic Imaging Repository) and heterogeneous PACS (Picture Archiving and Communication Systems) as well as mobile clients in the cloud ecosystem. Through using OpenID Connect as an open-source authentication and authorization service, deploying DI-r and PACS to private or community clouds should obtain equivalent security level to traditional computing model.

9418-19, Session 5

DICOM index tracker enterprise: advanced system for enterprise-wide quality assurance and patient safety monitoring

Min Zhang, Mayo Clinic Arizona (United States) and Arizona State Univ. (United States); William Pavlicek, Anshuman Panda, Mayo Clinic Arizona (United States); Steve G. Langer, Richard G. Morin, Kenneth A. Fetterly, Mayo Clinic (United States); Robert Paden, Mayo Clinic Arizona (United States); James Hanson, Arizona State Univ. (United States); Lin-Wei Wu, Mayo Clinic (United States); Teresa Wu, Arizona State Univ. (United States)

DICOM Index Tracker (DIT) is an integrated platform to harvest rich information available from Digital Imaging and Communications in Medicine (DICOM) to improve quality assurance in radiology practices. It is designed to capture and maintain longitudinal patient-specific exam indices of interests for all diagnostic and procedural uses of imaging modalities. Thus, it can effectively serve as a real time? quality assurance and patient safety monitoring tool. The foundation of DIT is an intelligent database system which stores the information accepted and parsed via a DICOM parser. The database system enables the basic dosimetry analysis. The success of DIT implementation at Mayo Clinic Arizona calls for the DIT deployment at the enterprise level (multi-site decentralized), which requires significant improvements. The main challenge, for geographically distributed multi-site

implementation, is the communication (network) delay and the scalability of the DICOM parser to handle the large volume of exams from different sites. To address this issue, DICOM receiver and parser are separated and decentralized by site. The next challenge is the great diversities in protocols between manufacturers, modalities and software versions. As a solution DIT II provides the configuration tool for scanner standardization across sites. Finally, advanced analytic engines are implemented online which enable real-time QA in DIT II.

9418-20, Session 5

Design challenges and gaps in standards in developing an interoperable zero footprint DI thin client for use in image-enabled electronic health record solutions

Arun Agrawal, Mohawk College (Canada); David Koff, McMaster Univ. (Canada); Peter Bak, AXON Medical Technologies Corp. (Canada); Duane Bender, Mohawk College (Canada); Jane Castelli, McMaster Univ. (Canada)

The deployment of regional and national Electronic Health Record solutions has been a focus of many countries throughout the past decade. A major challenge for these deployments has been support for ubiquitous image viewing. More specifically, these deployments require an imaging solution that can work over the Internet, leverage any point of service device: desktop, tablet, phone; and access imaging data from any source seamlessly. Whereas standards exist to enable ubiquitous image viewing, few if any solutions exist that leverage these standards and meet the challenge. Rather, most of the currently available web based DI viewing solutions are either proprietary solutions or require special plugins. We developed a true zero foot print browser based DI viewing solution based on the WADO and XDS.b-I standards to a) demonstrate that a truly ubiquitous image viewer can be deployed; b) identify the gaps in the current standards and the design challenges for developing such a solution. The objective was to develop a viewer which works on all modern browsers on both desktop and mobile devices. The implementation allows basic viewing functionalities of scroll, zoom, pan and window leveling (limited). The major gaps identified in the current DICOM WADO standards are a lack of ability to allow any kind of 3D reconstruction or MPR views. Other design challenges explored include considerations related to optimization of the solution for response time and low memory foot print.

9418-21, Session 5

Investigation into the need for ingesting foreign imaging exams into local systems and evaluation of the design challenges of Foreign Exam Management (FEM)

Lazar Milovanovic, McMaster Univ. (Canada); Arun Agarawal, Mohawk College (Canada); Peter Bak, AXON Medical Technologies Corp. (Canada) and McMaster Univ. (Canada); Duane Bender, Mohawk College (Canada); David Koff, Hamilton Health Sciences (Canada) and McMaster Univ. (Canada)

The deployment of regional and national Electronic Health Record solutions has been a focus of many countries throughout the past decade. Most of these deployments have taken the approach of "sharing" imaging exams via portals and web-based viewers. The motivation of portal/web-based access is driven by a) the perception that review of imaging exams via portal methods is satisfactory to all users and b) the perceived complexity of ingesting foreign exams into local systems. This research project set out to objectively evaluate who really needs foreign exams within their local systems, what those systems might be and how often this is required.

Working on the belief that FEM is required to support clinical workflow, the project implemented a FEM capability within an XDS.b-I domain to identify the design challenges and nuances associated with FEM.

9418-22, Session 5

Evaluation of DICOM Viewer Software for Workflow Integration in Clinical trials

Daniel Haak, Klaus Kabino, Thomas M. Deserno, RWTH Aachen Univ. (Germany)

Nowadays, data capture in clinical trials is performed using electronic case report forms (eCRFs) instead of paper-based CRFs. Automatic evaluation of entered data (e.g. by hard checks) and easy access to patient's data (e.g. via web browsers) improve data quality, save time and costs. During the last years, the open source project OpenClinica has been established as one of the world's leading electronic data capture systems (EDCS), offering powerful functionality for electronically collection, management and storage of clinical trial's data. However, due to missing integration, viewing of Digital Imaging and Communications in Medicine (DICOM) images in the eCRF is still not possible, although many DICOM viewer exists. This results in additional manual interactions steps in the data capture workflow of imaging clinical trials. In this paper, various strategies for integration of DICOM viewing functionality into eCRFs are discussed. Aiming at data, context and functional integration, each of these strategies includes its own system architecture based on integrated or separated DICOM data storing and viewing, respectively, presenting its specific requirements for viewers. These requirements are collected in a catalog of 30 criteria regarding license, platform, interfaces, header viewing, 2D image viewing, 3D volume viewing and support. A survey of 25 software projects with DICOM viewing functionality is performed, resulting in a software rating regarding each system architecture. In conclusion, a lack of support for interfaces in common viewers is identified, which may be solved by extending of open source viewers functionality.

9418-43, Session 5

Future trends in picture archiving and communication system (PACS)

Mona M. Alhajeri, Malcolm Clarke, Brunel Univ. (United Kingdom)

Objective: This research investigates the needs and opinions of radiologists on the use of enhanced information technologies and approaches to improve the functionality of Picture Archiving and Communication Systems (PACS).

Method: Six interviews were conducted in the main governmental hospital of Kuwait (AL-Sabah Hospital) with radiologists including two senior radiologists, two junior radiologists, and two radiologists undertaking the Irish radiology board.

Results: The radiologists identified a number of limitations that exist in current PACS and requirements to expand usability and functionality. However it was the case that some of the radiologists have little knowledge about the advanced trends in PACS.

Four preliminary themes emerged from the thematic analysis of data, which include: (1) Traditional PACS and its limitations; (2) Clinician requirements in using PACS; (3) Use of web based solutions of PACS; (4) PACS in mobile phones.

The research showed that there are various features that if incorporated will enhance usability of PACS and increase its functionality such as web based solutions for PACS and PACS in mobile phones.

Conclusion: It is widely recognised that PACS has limitations. This research has identified themes that, when incorporated, will enhance the functionality of PACS and provide better quality clinical practice.

This research highlighted some future trends on PACS, such as web based

solutions for PACS and PACS in mobile phones. The findings from this research can be used as recommendations to vendors and medical institutes to consider when undertaking implementation of PACS and training future radiologists.

9418-23, Session 6

Extraction of endoscopic images for biomedical figure classification

Zhiyun Xue, Daekeun You, Suchet K. Chachra, Sameer K. Antani, L. Rodney Long, Dina Demner-Fushman, George R. Thoma, National Library of Medicine (United States)

Modality filtering is an important feature in biomedical image searching systems and may significantly improve the retrieval performance of the system. This paper presents a new method for extracting endoscopic image figures from the biomedical literature, where they are found to have highly diverse content and large variability in appearance. Our proposed method consists of three main stages: tissue image extraction, endoscopic image candidate extraction, and ophthalmic image filtering. For tissue image extraction we use image patch level clustering and MRF relabeling to detect images containing skin/tissue regions. Then we find candidate endoscopic images by exploiting the round shape characteristics that commonly appear in these images. However, this step needs to accommodate the issue that most endoscopic regions are not entirely round. In the third step we filter out the ophthalmic images which have very similar shape characteristics as the endoscopic images. We do this by using text information, specifically, anatomy terms, extracted from the figure caption. We tested and evaluated our method on a dataset of 110,000 photograph figures, and achieved promising precision and recall rates of 87% and 84%, respectively.

9418-24, Session 6

Lung boundary detection in pediatric chest x-rays

Sema Candemir, Sameer K. Antani, Stefan R. Jaeger, Lister Hill National Ctr. for Biomedical Communications (United States); Renee Browning, National Institute of Allergy and Infectious Diseases (United States); George R. Thoma, Lister Hill National Ctr. for Biomedical Communications (United States)

Tuberculosis (TB) is a major public health problem worldwide, and highly prevalent in developing countries. According to the World Health Organization (WHO), over 95% of TB deaths occur in low- and middle-income countries that often have under-resourced health care systems. In an effort to aid population screening in such resource challenged settings, the U.S. National Library of Medicine has developed a chest X-ray (CXR) screening system that provides a pre-decision on pulmonary abnormalities. When the system is presented with a digital CXR image from the PACS or an imaging source, it automatically identifies the lung regions in the image, extracts image features, and classifies the image as normal or abnormal using trained machine-learning algorithms. The system has been trained on adult CXR images, and this article presents enhancements toward including pediatric CXR images. Our adult lung boundary detection algorithm is model-based. We note the lung shape differences during pediatric developmental stages, and adulthood, and propose building new lung models suitable for pediatric developmental stages. In this study, we quantify changes in lung shape from infancy to adulthood toward enhancing our lung segmentation algorithm. Our initial findings suggest pediatric age groupings of 0 - 23 months, 2 - 9 years, and 10 - 18 years. We present justification for our groupings, and early segmentation results. We will report on the quality of boundary detection algorithm with the pediatric lung models in the expanded version of this paper.

9418-25, Session 6

Sampling probability distributions of lesions in mammograms

Padraig T. Looney, Lucy M. Warren, The Royal Surrey County Hospital NHS Trust (United Kingdom); David R. Dance, Royal Surrey County Hospital NHS Trust (United Kingdom); Kenneth C. Young, The Royal Surrey County Hospital NHS Trust (United Kingdom) and Univ. of Surrey (United Kingdom)

To perform image perception studies lesions have previously been inserted into normal mammograms. In this work a method has been developed that allows for sampling of lesion positions across the cranio-caudal and medio-lateral radiographic projections in mammography to ensure that the locations of insertion are realistic.

6825 mammograms from our mammography image database were segmented to find the breast outline. The outlines were averaged and smoothed to produce an average outline for each laterality and radiographic projection.

Lesions in 3304 mammograms with malignant findings were mapped on to the average outline using piecewise affine transforms. A four dimensional probability distribution function was found from the lesion location in the cranio-caudal and medio-lateral radiographic projections for calcification and non-calcification lesions. Lesion locations sampled from this probability distribution function were mapped on to mammograms by creating a piecewise affine transform from the average outline to the outline of the mammogram and mapping the coordinates of the sampled lesions.

The four dimensional probability distribution function was validated by comparing it to the two dimensional distributions found by considering each radiographic projection and laterality independently. The correlation of the location of the lesions sampled from the four dimensional probability distribution function across radiographic projections was shown to match the correlation of the locations of the mapped lesion locations.

The current system has been implemented as a web-service on a server using the Python Django framework. The server performs the sampling, performs the mapping and returns the results in a javascript object notation format.

9418-26, Session 6

Medical case-based retrieval: integrating query MeSH terms for query-adaptive multi-modal fusion

Alba García Seco de Herrera, Antonio Foncubierta Rodríguez, Henning Mueller, HES-SO Valais (Switzerland)

Advances in medical knowledge give clinicians more objective information for a diagnosis. Therefore, there is an increasing need for bibliographic search engines which can provide services that help facilitate a more rapid search for information.

The ImageCLEFmed evaluation benchmark proposes a medical case–based retrieval task. This task aims to retrieve articles from the biomedical literature that are relevant for differential diagnosis of query cases including a textual description and several images. In the context of this campaign many approaches have been investigated showing that the fusion of visual and text information improves the precision of the retrieval. Moreover, query expansion is an standard method for the text retrieval literature which can use the MeSH (Medical Subject Headings) ontology in the medical field.

In this paper, a new query reweighting method is presented. The proposed method integrates text information contained in MeSH terms extracted from the case description into visual queries. It recalculates visual feature vectors based on the polysemy relation between query MeSH terms and query visual words.

Preliminary results show that this approach can increase performance of the retrieval.

9418-27, Session 6

Clinical evaluation of using semantic searching engine for radiological imaging services in RIS-integrated PACS

Tonghui Ling, Kai Zhang, Yuanyuan Yang, Shanghai Institute of Technical Physics (China); Yanqing Hua, HuaDong Hospital (China); Jianguo Zhang, Shanghai Institute of Technical Physics (China)

Purpose:

Content based searching with both semantic and image visual features from imaging information systems PACS/RIS are very important to radiologists in image diagnosis, research and education. We had designed a semantic searching engine (SSE) for radiological imaging to search both reports and images in RIS-integrated PACS environment. In this presentation, we present evaluation results of this SSE about how it impacting the radiologists behaviors in reporting for different kinds of examinations, and how it improving the performance of retrieval and usage of historical images in RIS-integrated PACS, and discuss its potential application in big data mining of medical images.

Method and Materials:

The SSE for radiological imaging was built with semantic knowledgebase for Chinese radiological reporting, natural language processing engine for Chinese free texts, and inverting index. The SSEs were integrated into clinical RIS/PACS systems in one large hospital in Shanghai and have been operating for more than three years. A HIPAA-Compliant Automatic Monitoring System was used to track and analyze the user behaviors of using the SSE to retrieve the historical reports and images. There were about 800 to 1000 exam/day and 200,000 exam/Year performed in this hospital, and about 40 to 50 users, included of senior and junior radiologists as well as students and residents, using the SSE in their daily imaging services and studying.

Results:

The events of operation and usage of SSE in RIS/PACS have been tracked and analyzed in one hospital for more than three years. The annual increasing ratios of using SSE were more than 35% in first three years. The SSE was mostly used to search MR and CT studies, but MR images were more frequently searched than CT images. The SSE was more helpful and useful to young radiologists (usage:15-23%), residents (17-22%), refresher (17-28%), and students (26-35%). The SSE can increase the retrieval ratio (12%) of historic studies of PACS comparing to typical PACS querying and retrieval, especially for those studies archived for more than one year longer in PACS.

New Technologies and Results to be Presented:

The semantic knowledgebase for Chinese radiological reporting, natural language processing engine for Chinese free texts, and inverting index was used to build the SSE. The presented search engine is extremely useful to assist radiologists, medical researchers and students to mine meaningful information from PACS and RIS. It also can potentially be used to discover valuable information from big data of medical images.

Conclusions:

SSEs have been accepted to use as useful searching tool by radiologists in their clinical imaging services, research and study. It is more often used for searching difficult studies, and is more helpful and useful to young radiologists. It can increase the usages of historic studies of PACS, especially for those studies archived in PACS more than one year longer.

9418-28, Session 7

A Concept-Based Interactive Biomedical Image Retrieval Approach using Visualness and Spatial Information

Md Mahmudur Rahman, Sameer K. Antani, Dina Demner-Fushman, George R. Thoma, National Library of Medicine (United States)

This paper presents a novel approach to biomedical image retrieval by mapping image regions to local visual concepts, and representing images in a weighted entropy-based concept feature space. The term "visual concept" refers to perceptually distinguishable visual patches that are identified locally in image regions and can be mapped to a glossary of imaging terms. Further, the visual significance of concepts is measured as Shannon entropy of pixel values in image patches, and is used to refine the feature vector. Moreover, the system can assist user in interactively select a Region-Of-Interest (ROI) and search for similar images based on matching of underlying concepts of query image ROI and overlapping regions of database images. Finally, a spatial verification is used as a post-processing step to improve retrieval results. The hypothesis that such approaches would improve biomedical image retrieval is validated through experiments on a data set of 450 lung CT images extracted from

9418-29, Session 7

Mass classification in mammography with multi-agent based fusion of human and machine intelligence

Dongdong Xi, Ming Fan, LiHua Li, Hangzhou Dianzi Univ. (China); Juan Zhang, Zhejiang Cancer Hospital (China); Yanna Shan, Hangzhou First People's Hospital (China); Gang Dai, Zhejiang Cancer Hospital (China); Bin Zheng, Univ. of Pittsburgh (United States)

Although the computer-aided diagnosis (CAD) system can be applied for classifying the breast masses, the effects of this method on improvement of the radiologist' accuracy for distinguishing malignant from benign lesions still remain unclear. This study provided a novel method to classify breast masses by integrating the intelligence of human and machine. In this research, 224 breast masses were selected in mammography from database of DDSM with Breast Imaging Reporting and Data System (BI-RADS) categories. Three observers (a senior and a junior radiologist, as well as a radiology resident) were employed to independently read and classify these masses utilizing the Positive Predictive Values (PPV) for each BI-RADS category. Meanwhile, a CAD system was also implemented for classification of these breast masses between malignant and benign. To combine the decisions from the radiologists and CAD, the fusion method of the Multi-Agent was provided. Significant improvements are observed for the fusion system over solely radiologist or CAD. The area under the receiver operating characteristic curve (AUC) of the fusion system increased by 9.6%, 10.3% and 21% compared to that of radiologists with senior, junior and resident level, respectively. In addition, the AUC of this method based on the fusion of each radiologist and CAD are 3.5%, 3.6% and 3.3% higher than that of CAD alone. Finally, the fusion of the three radiologists with CAD achieved AUC value of 0.957, which was 5.6% larger compared to CAD. Our results indicated that the proposed fusion method has better performance than radiologist or CAD alone.

9418-30, Session 7

Association between dynamic features of breast DCE-MR imaging and clinical response of neoadjuvant chemotherapy: a preliminary analysis

Lijuan Huang, Ming Fan, Lihua Li, Hangzhou Dianzi Univ. (China); Juan Zhang, Guoliang Shao, Zhejiang Cancer Hospital (China); Bin Zheng, Univ. of Pittsburgh (United States)

Neoadjuvant chemotherapy (NACT) is being increasingly used in the

management of patients with breast cancer for systemically reducing the size of primary tumor before surgery in order to improve survival. The clinical response of patients to NACT is correlated with reduced or abolished of their primary tumor, which is important for treatment in the next stage. Recently, the dynamic contrast-enhanced magnetic resonance imaging (DCE-MRI) is used for evaluation of the response of patients to NACT. To measure this correlation, we extracted the dynamic features from the DCE-MRI and performed association analysis between these features and the clinical response to NACT. In this study, 59 patients are screened before NACT, of which 47 are complete or partial response, and 12 are no response. We segmented the breast areas depicted on each MR image by a computer-aided diagnosis (CAD) scheme, registered images acquired from the sequential MR image scan series, and calculated eighteen features extracted from DCE-MRI. For better classification, features are selected by using Genetic Algorithm and six features are thus remained. We classified patients into response and no response cases by implementing SVM method. The accuracy, sensitivity and specificity of this method with reduced number of features are 87%, 95.74% and 50%, respectively. In addition, the calculated area under a receiver operating characteristic (ROC) curve is 0.79±0.04. This study indicated that the features of DCE-MRI of breast cancer are associated with the clinical response and could be helpful for evaluation of NACT in treatment of breast cancer.

9418-31, Session 7

Automated identification of retained surgical items in radiological images

Gady Agam, Lin Gan, Illinois Institute of Technology (United States) and Rapid Medical Technologies (United States); Vicko Gluncic, Mario Moric, Rush Univ. Medical Ctr. (United States) and Rapid Medical Technologies (United States)

Retained surgical items (RSIs) in patients is a major operating room (OR) patient safety concern. An RSI is any surgical tool, sponge, needle or other item inadvertently left in a patient's body during the course of surgery. If left undetected, RSIs may lead to serious negative health consequences such as sepsis, internal bleeding, and even death. To help physicians efficiently and effectively detect RSIs, we are developing computer-aided detection (CADe) software for X-ray (XR) image analysis, utilizing large amounts of currently available image data to produce a clinically effective RSI detection system. Physician analysis of XRs for the purpose of RSI detection is a relatively lengthy process that may take up to 45 minutes to complete. It is also error prone due to the relatively low acuity of the human eye for RSIs in XR images. The system we are developing is based on computer vision and machine learning algorithms. We address the problem of low incidence by proposing synthesis algorithms. The CADe software we are developing may be integrated into a picture archiving and communication system (PACS), be implemented as a stand-alone software application, or be integrated into portable XR machine software through application programming interfaces.

Preliminary experimental results on actual XR images demonstrate the effectiveness of the proposed approach.

9418-32, Session 7

Design and evaluation of an imaging informatics system for analytics-based decision support in radiation therapy

Ruchi R. Deshpande, The Univ. of Southern California (United States); John J. DeMarco, Univ. of California, Los Angeles (United States); Brent J. Liu, The Univ. of Southern California (United States)

We have developed a comprehensive DICOM RT specific database of retrospective treatment planning data for radiation therapy of head and neck cancer. Further, we have designed and built an imaging informatics module that utilizes this database to perform data mining. The end-goal of this data mining system is to provide radiation therapy decision support for incoming head and neck cancer patients, by identifying best practices from previous patients who had the most similar tumor geometries. Since the performance of such systems often depends on the size and quality of the retrospective database, we have also placed an emphasis on developing infrastructure and strategies to encourage data sharing and participation from multiple institutions. The infrastructure and decision support algorithm have both been tested and evaluated with 51 sets of retrospective treatment planning data of head and neck cancer patients. We will present the overall design and architecture of our system, an overview of our decision support mechanism as well as the results of our evaluation.

9418-18, Session PSMon

The standardization of super resolution optical microscopic images based on DICOM

Wei Xia, Xin Gao, Suzhou Institute of Biomedical Engineering and Technology (China)

Super resolution optical microscopy allows the capture of images with a higher resolution than the diffraction limit. However, due to the lack of a standard format, the processing, visualization, transfer, and exchange of Super Resolution Optical Microscope (SROM) images are inconvenient. In this work, we present an approach to standardize the SROM images based on the Digital Imaging and Communication in Medicine (DICOM) standard. The SROM images and associated information are encapsulated and converted to DICOM images based on the Visible Light Microscopic Image Information Object Definition of DICOM. The new generated SROM images in DICOM format can be displayed, processed, transferred, and exchanged by using most medical image processing tools.

9418-33, Session PSMon

A web-based solution for 3D medical image visualization

Xiaoshuai Hou, Jianguo Zhang, Jianyong Sun, Shanghai Institute of Technical Physics (China)

Purpose: With the rapid development of medical imaging devices, more and more high-resolution 3D medical images have been produced. These high-resolution 3D medical volumetric data are very large in size, ranging from hundreds of megabytes to several gigabytes. However, most existing medical image applications perform the image processing and analysis on the client side by downloading the whole volumetric data from PACS server, which are time-consuming and inconvenient. The users need to reinstall the medical applications or update their hardware every time new software edition is released. So in order to deal with these challenges, we present this web-based solution for interactive applications of 3D medical image visualization.

Methods and Materials: We designed the web-based solution for Interactive applications of 3D medical image visualization, which satisfies requirements of the development of medical informatics. There are three major components in our solution including: (1) Graphical User Interface: The web user interface adopt HTML5 and JavaScript to implement Rich Internet Applications without installing additional client-side software. Through this user interface, the users can set up transfer functions or window/level presets which are used on the server side; (2) Client Server communication layer: With AJAX, only the necessary data is transferred back and forth between the client and the web server so as to enhance user experience; (3) Server-side applications layer: The implementation of our visualization algorithms are based on The Visualization Toolkit(VTK), an open-source, freely available software system for 3D computer graphics, image processing and visualization. The VTK library is widely used in medical

imaging applications and can be developed with C++, Java and so on.

Results: We have explored the feasibility of volume rendering of medical data sets using VTK on Linux OS. After several months of investigation, we have found that GPU-accelerated volume rendering using VTK is a better alternative compared to using JCUDA on Linux OS. What's more, most of the desktop browsers including Internet Explorer, Firefox, Chrome, Safari and Opera support HTML5. Considering these facts, this solution guarantee that the users can access the visualization services in real time through these major web browsers on their PCs or mobile devices.

New Technologies and Results to be Presented: Our solution presented in this paper uses GPU accelerated medical image processing based on VTK to generate visualizations on the server side and HTML5 web browser to display images on the client side. This solution is pure web-based, interactive and extendable. The ultimate goal is to enable the users to access the 3D medical image visualization as a service over the network.

Conclusions: We presented a web-based solution for Interactive applications of 3D medical image visualization which satisfies our lab's development requirement. The first phase of our project was to implement the common visualization techniques such as Multi-planar reconstruction, Maximum Intensity Projection and Volume Rendering to verify the feasibility of visualization techniques implemented using VTK on Linux OS. The feedback from our previous investigation indicates that volume rendering based on VTK on the server side is practicable for our project.

9418-34, Session PSMon

Imaging informatics system to support animal studies for treating pain in spinal cord injury utilizing proton radiotherapy

Sneha K. Verma, Brent J. Liu, The Univ. of Southern California (United States); Daila S. Gridley, Xiao W. Mao, Loma Linda Univ. (United States)

In previous years we demonstrated an imaging informatics system designed to support multi-institutional research focused on the utilization of proton therapy for treating spinal cord injury (SCI)-related pain. This year we will demonstrate an update on the system with new modules added to perform image processing on evaluation data using protein-staining methods to observe effects of proton therapy. The overarching goal of the research is to determine the effectiveness of using the proton beam for treating SCI-related neuropathic pain as an alternative to invasive surgical lesioning. The research is a joint collaboration between three major institutes, University of Southern California (data collection/integration and image analysis), Spinal Cord Institute VA Healthcare System, Long Beach (patient subject recruitment), and Loma Linda University and Medical Center (human and preclinical animal studies). The system that we are presenting is one its kind which is capable of integrating a large range of data types, including text data, imaging data, DICOM objects from proton therapy treatment and pathological data. For multi-institutional studies, keeping data secure and integrated is very crucial. Different kinds of data within the study workflow are generated at different stages and different groups of people who process and analyze them in order to see hidden patterns within healthcare data from a broader perspective. The uniqueness of our system relies on the fact that it is platform independent and web-based which makes it very useful in such a large-scale study.

9418-35, Session PSMon

Quantitative Imaging Features: Extension of the Oncology Medical Image Database

Mishal N. Patel, Padraig T. Looney, Kenneth C. Young, Mark D. Halling-Brown, The Royal Surrey County Hospital NHS Trust (United Kingdom)

Radiological imaging is fundamental within the healthcare industry and

has become routinely adopted for diagnosis, disease monitoring and treatment planning. With the advent of digital imaging modalities and the rapid growth in both diagnostic and therapeutic imaging, the ability to able to harness this large influx of data is of paramount. The Oncology Medical Image Database (OMI-DB) 1,2 was to provide a centralised, fully annotated dataset for research. The database contains both processed and unprocessed images, associated data, and annotations and where applicable expert determined ground truths describing features of interest. Medical imaging provides the ability to detect and localise many changes that are important to determine whether a disease is present or a therapy is effective by depicting alterations in anatomic, physiologic, biochemical or molecular process. Quantitative imaging features are sensitive, specific, accurate and reproducible imaging measures of these changes.

Here, we describe an extension the OMI-DB whereby comprehensive range of imaging features and descriptors are pre-calculated using a high throughput approach. The ability to calculate multiple imaging features and data from the acquired images would be valuable and facilitate further research applications investigating detection, prognosis, and classification. The resultant data store has been used to build computational models to investigate if such features are sufficient to predict patients with high risk of developing breast cancer. This can be achieved by analysis of the contralateral and prior mammograms of existing cancer cases available in the OMI-DB to build a profile that can be compared against known normal cases in a predictive fashion.

9418-36, Session PSMon

Open-source radiation exposure extraction engine (RE3) for dose monitoring

Samuel Weisenthal, Les R. Folio, Vana Derderian, Ronald M. Summers, Jianhua Yao, National Institutes of Health (United States)

Our goal was to investigate the feasibility of an open-source, PACS-integrated, DICOM header-based tool that automatically provides granular data for monitoring of CT radiation exposure. To do so, we constructed a radiation exposure extraction engine (RE3) that is seamlessly connected to the PACS using open-source components and the digital imaging and communications in medicine (DICOM) toolkit (DCMTK) that runs concurrently within the clinical workflow. We validated RE3's ability to determine the number of acquisitions and calculate the exposure metric dose length product (DLP) by comparing its output to the vendor dose pages. RE3 output closely correlated to the dose pages for both contiguously acquired exams (R2 =0.9987) and non-contiguously acquired exams (R2=0.9994). RE3 is an open-source, automated radiation monitoring program to provide study-, series-, and slice-level radiation data.

9418-38, Session PSMon

Teleradiology mobile internet system and home care medical system with a new information security solution

Hitoshi Satoh, Hi Sato, Tokai Gakuin Univ. (Japan)

We are studying the secret sharing scheme and the tokenization as a method safely to store or to transmit the confidential medical information. Secret sharing scheme is a method of dividing the confidential medical information into two or more tallies. Our method has the function of automatic backup. With automatic backup technology, if there is a failure in a single tally, there is redundant data already copied to other tally. Confidential information is preserved at an individual Data Center connected through internet because individual medical information cannot be decoded by using one tally at all. Therefore, even if one of the Data Centers is struck and information is damaged due to the large area disaster, the confidential medical information can be decoded by using the tallies preserved at the data center to which it escapes damage. Moreover, by using tokenization,

the history information of dividing the confidential medical information into two or more tallies is prevented from lying scattered by replacing the history information with another character string. As a result, information is available only to those who have rightful access it and the sender of a message and the message itself are verified at the receiving point. We propose a new information transmission method and a new information storage method with a new information security solution.

9418-39, Session PSMon

Operation and evaluation of e-Science platform for translational biomedical imaging research

Tusheng Wang, Yuanyuan Yang, Mingqing Wang, Jianguo Zhang, Shanghai Institute of Technical Physics (China); Jianlin Liu, Shanghai Jiaotong Univ. (China)

Materials and Methods:

Based on the requirements of enabling multiple disciplines of medical researchers, clinical physicians and biomedical engineers collaboratively working to solve the problems related to disease discovery, diagnosis and therapy. The e-Science platform was designed with service-oriented architecture (SOA) integrated with grid-based image management. It consisted of multiple function components of sample registration, project/user manager, collaborative controlling server, task assignment and tracking server, high performance computing cluster (HPCC), tele-video conferencing system et al. We used MTOM/XOP Web Service to enable DICOM and non-DICOM biomedical image communication and management cross hospitals and academic institutions, and built an intelligent monitoring and management system to improve the robustness, reliability and service continuity of this e-Science platform, referring ATNA and XMPP. During two-years running, as data volume and experiments increases, several components was developed such as FTP for authentication and upload, Map/Reduce for count and analyze metadata of big data. After statistics, the system could provide some suggestive conclusions covering from research funding to output.

Results:

The developed e-Science system has deployed in three sites: SSRS, Micro-PET/CT research center of Ruijing hospital, and Med-X Research Institute of Shanghai Jiaotong University (data center). The system had collected data sets of more than one hundred biomedical imaging experiments from researchers in these three institutions, as well as Fudan University Cancer Hospital (FUCH). The academic researchers and clinical physicians can used this system to share acquired biomedical image data from SSRS and Micro-PET/CT among the members of a group cross these three sites, and can perform tele-imaging from Ruijing Hospital and Med-X Research Institute to SSRS.

New Technologies and Results to be Presented:

A Hadoop Map/Reduce mechanism was applied to count and analyze metadata information of all experiment data. A FTP Database Authentication method is used to keep portal of e-Science platform and FTP data transmission use the same user authentication collection.

Conclusions:

We presented a novel e-Science platform which can enable multiple disciplines of biomedical research cross multiple academic institutions and hospitals. The developed e-Science system has deployed in three sites: SSRS, Micro-PET/CT research center of Ruijing hospital, and Med-X Research Institute of Shanghai Jiaotong University (data center). During two-years running, the system shows the ability to help academic researchers and clinical physicians backup and share acquired huge biomedical image data among the members of a group cross institutions, and provides HPC-based computing for post processing of biomedical image.

9418-41, Session PSMon

DTI - DKI Fitting: a graphical toolbox for estimation and visualization of diffusion tensor and diffusion kurtosis imaging

Rajikha Raja, Neelam Sinha, International Institute of Information Technology, Bangalore (India); Jitender Saini, National Institute of Mental Health and Neuro Sciences (India)

Diffusion weighted magnetic resonance images(DW-MRI) such as diffusion tensor imaging(DTI) and diffusion kurtosis imaging(DKI) are widely used in understanding the complex cellular microstructures non-invasively. With the increased usage of DTI and DKI in the recent years, the need for software packages for processing magnetic resonance(MR) diffusion data has also gained much importance. We have developed a new graphical toolkit named 'DTI-DKI fitting' which is an interactive software for processing diffusion MR images is presented for the first time. The features included in this toolbox are processing of 4D diffusion weighted data in formats such as Dicom and NIFTI, estimation of diffusion tensor and diffusion kurtosis parametric maps and visualization of those parametric maps. The toolbox is developed in Matlab as a stand alone application and main advantage being simple with minimal functionalities and user friendly. The functionalities of the toolbox are tested with multiple DW MR data acquired from normal and abnormal subjects.

9418-42, Session PSMon

A novel image interpreting system for radiologists: tumor response monitoring through PACS

Mustafa Bayraktar, UALR (United States); Umit Topaloglu, James McDonald, Laura F. Hutchins, Univ. of Arkansas for Medical Sciences (United States)

Clinicians rely on radiologist for the imaging interpretation as well as annotation and markup. Due to software disconnects and some communication hurdles around the ordering images, the clinics usually don't receive the imaging study results in a precision they need for the treatment of the patient. That plays vital roles in chronic diseases such as cancer where tumor progression should be closely monitored. Although huge progress made to date to overcome such problems, due to personnel training deficiencies, inconsistencies on adopting accepted standards and weak communication between the two parties, many times the desired information cannot be captured or conveyed properly and obtained information cannot be analyzed in a timely fashion or intended purposes. This paper attempts to provide a solution to the aforementioned problem by creating a system with four distinct functionalities. First, we propose bringing a referent tracking based method for the tracking response of lesions over time and the treatment modality. Second, we suggest an agile auto correction system to help those interpreting medical images better utilize the accepted vocabulary and markup patterns determined by NIH (National Institute of Health) recommended RECIST standards (Response Evaluation Criteria in Solid Tumors). Third, to reinforce accuracy, we will then automatically reprocess these slices and segment lesions, comparing them to the radiologists` manual delineations previously interpreted by RECIST. And, fourth we will then create a clinical decision support system that will recommend annotation on similar slices for radiologists' assessment and diagnosis.

Conference 9419: Ultrasonic Imaging and Tomography

Sunday - Monday 22–23 February 2015

Part of Proceedings of SPIE Vol. 9419 Medical Imaging 2015: Ultrasonic Imaging and Tomography

9419-1, Session 1

Transverse oscillation vector flow imaging for transthoracic echocardiography

David P. Bradway, Technical Univ. of Denmark (Denmark); Kristoffer L. Hansen, Michael B. Nielsen, Copenhagen Univ. Hospital Rigshopitalet (Denmark); Jørgen A. Jensen, Technical Univ. of Denmark (Denmark)

This paper presents the first results of in vivo vector velocity flow imaging using the transverse oscillation method with a transthoracic cardiac approach. This novel imaging mode reveals both the magnitude and direction of the blood velocity without reliance on angle-correction of 1-D estimates. Data were acquired using the SARUS experimental ultrasound scanner connected to a intercostal phased array probe. The acquisition sequence was composed of interleaved frames of B-mode and vector velocity flow imaging.

A flow pump was programmed for constant flow for in vitro acquisitions at varying depths in a tissue-mimicking fluid. Additionally, mitral, aortic, and tricuspid valves of two healthy volunteers were scanned from intercostal acoustic windows. The acquired RF data were beamformed via the Transverse Oscillation method, and fourth-order estimators were employed for the velocity estimation.

The resulting images were compared with those from conventional spectral Doppler and color flow mapping sequences. VFI is shown to be an accurate, clinically-feasible tool which enables new flexibility for choosing acoustic windows and measuring turbulent flow patterns and velocities.

9419-2, Session 1

Endoleak and thrombus characterization with dynamic elastography after endoleak embolization following aneurysm endovascular repair

Antony Bertrand-Grenier, Ctr. Hospitalier de l'Univ. de Montréal (Canada); Fatemeh Zehtabi, Ctr Hospitalier de l'Univ. de Montréal (Canada) and Ecole de Technologie Supérieure (Canada) and Endovascular Biomaterials Laboratory (LBeV) (Canada); Claude Kauffmann, Guy Cloutier, Ctr. Hospitalier de l'Univ. de Montréal (Canada); Sophie Lerouge, Ctr Hospitalier de l'Univ. de Montréal (Canada) and Ecole de Technologie Supérieure (Canada); Gilles Soulez, Ctr. Hospitalier de l'Univ. de Montréal (Canada)

PURPOSE: The purpose of this study was to characterize in a canine model of aneurysm endovascular repair (EVAR) residual endoleak and thrombus organization with Supersonic Shear Imaging (SSI) after endoleak embolization.

METHODS AND MATERIALS: EVAR was done with creation of type I endoleak in eighteen aneurysms created in nine dogs (common iliacs arteries). Two embolization gels (Chitosan (Chi) or Chitosan-Sodium-Tetradecyl-Sulfate (Chi-STS)) were injected in the sac to seal the endoleak and promote healing. SSI and Doppler Ultrasound were performed at baseline (implantation, 1-week, 1-month, 3-months) whereas angiography and CT-scan were performed at sacrifice. Macroscopic and histopathological analyses were processed to identify and segment five different regions of interest (ROIs) (endoleak, fresh or organized thrombus, Chi or Chi-STS). Elasticity modulus values were compared in these ROIs.

RESULTS: At sacrifice, ten aneurysms had endoleaks, nine had fresh

thrombus, fifteen had organized thrombus and three were completely sealed. At 3 months, elasticity modulus (in kPa) of 0.1±0.2, 9.2±3.5, 47.3±25.7, 55.9±21.7 and 69.6±29.0 were respectively found in endoleak, fresh and organized thrombus, Chi and Chi-STS regions. Elasticity values of endoleak and fresh thrombus areas were significantly lower than organized thrombus, Chi and Chi-STS areas (p<0.001). Elasticity values of fresh thrombus ranged between 3 and 19 kPa (8.7±3.6 kPa) at 1-week and 30.2±13.8 kPa at 3-months indicating that SSI can evaluate thrombus maturation. Aneurysm with fresh thrombus did not shrink as fast as aneurysm with only organized thrombus.

CONCLUSION: The results show that SSI was able to characterize thrombus organization, embolization agents and healing over time after endoleak embolization following EVAR.

9419-3, Session 1

Automated hierarchical time gain compensation for in-vivo ultrasound umaging

Ramin Moshavegh, Martin C. Hemmsen, Technical Univ. of Denmark (Denmark); Bo Martins, BK Medical (Denmark); Andreas H. Brandt, Kristoffer L. Hansen, Copenhagen Univ. Hospital Rigshopitalet (Denmark); Michael Bachmann Nielsen M.D., Copenhagen University Hospital (Denmark); Jørgen A. Jensen, Technical Univ. of Denmark (Denmark)

Time gain compensation (TGC) is essential to ensure the optimal image quality of the clinical ultrasound scans. The majority of recently proposed TGC algorithms fail to compensate for overall gain when large fluid collections within the scan plane are present which change the attenuation distribution drastically. This paper presents an automated hierarchical TGC (AHTGC) algorithm that accurately adapts to the large attenuation variation between different types of tissues. The novelty of the algorithm stems from a distinct step in which 2-D attenuation maps of the scanned media are used to control the gain range and reduce the noticeably elevated gain values inside anechoic regions. This is the first study in which 2-D attenuation information of the medium is used to correct the gain in the most problematic ultrasound sequences of large anechoic regions. The proposed algorithm was applied to a set of 44 in vivo abdominal movie sequences each containing 15 frames. Matching Pairs of in vivo sequences, unprocessed and processed with the proposed AHTGC were visualized side by side and evaluated by two radiologists in terms of image quality. Wilcoxon signed-rank test was used to evaluate whether radiologists preferred the processed sequences or the unprocessed data. The results indicate that the average VAS score is positive (p-value: 2.34E?13) and estimated to be 1.01 (95% CI: 0.85; 1.16) favoring the processed data with the proposed AHTGC algorithm. Two radiologists consistently found the processed data better than un-processed data.

9419-4, Session 1

Characterization of neonatal patients with intraventricular hemorrhage using 3D ultrasound cerebral ventricle volumes

Jessica Kishimoto, Aaron Fenster, Robarts Research Institute (Canada); David S. C. Lee, Sandrine de Ribaupierre, London Health Sciences Ctr. (Canada)

One of the major non-congenital cause of neurological impairment among neonates born very preterm is intraventricular hemorrhage (IVH) - bleeding within the lateral ventricles.

Most IVH patients will have a transient period of ventricle dilation that resolves spontaneously. However, those patients most at risk of long-term impairment are those who have progressive ventricle dilation as this causes macrocephaly, an abnormally enlarged head, then later causes increases intracranial pressure (ICP). 2D ultrasound (US) images through the fontanelles of the patients are serially acquired to monitor the progression of the ventricle dilation. These images are used to determine when interventional therapies such as needle aspiration of the built up CSF might be indicated for a patient. Initial therapies usually begin during the third week of life. Such interventions have been shown to decrease morbidity and mortality in IVH patients; however, this comes with risks of further hemorrhage or infection; therefore only patients requiring it should be treated.

Previously we have developed and validated a 3D US system to monitor the progression of ventricle volumes (VV) in IVH patients. This system has been validated using phantoms and a small set of patient images.

The aim of this work is to determine the ability of 3D US generated VV to categorize patients into those who will require interventional therapies, and those who will have spontaneous resolution. Patients with higher risks could therefore be monitored better, by re-allocating some of the resources as the low risks infants would need less monitoring.

9419-5, Session 1

3D in vivo imaging of rat hearts by high frequency ultrasound and its application in myofiber orientation wrapping

Xulei Qin, Silun Wang, Ming Shen, Xiaodong Zhang, Emory Univ. (United States); Stamatios Lerakis, Emory Univ (United States); Mary B. Wagner, Baowei Fei, Emory Univ. (United States)

Cardiac ultrasound plays an important role in the imaging of hearts in basic cardiovascular research and clinical examinations. 3D ultrasound imaging can provide the geometry or motion information of the cardiac volume. Especially, the wrapping of cardiac fiber orientations to the ultrasound volume could supply useful information of stress distributions and the electric action spreading. However, how to acquire 3D ultrasound volumes of small animal heart in vivo for cardiac fiber wrapping is still a challenging problem. In this study, we provide an approach to acquire 3D ultrasound volumes of the rat hearts in vivo. The comparison between both in vivo and ex vivo geometries indicated 90.1% Dice similarity. Additionally, the evaluations of the cardiac fiber orientation wrapping errors were 24.7° for the acute angle error and were 22.4° for the inclination angle error. Thus, this 3D ultrasound imaging and fiber orientation estimation technique has potential applications in cardiac imaging.

9419-6, Session 2

Synergistic integration of photoacoustic and ultrasound computed tomography
(Keynote Presentation)

Mark A. Anastasio, Washington Univ. in St. Louis (United States)

Photoacoustic computed tomography (PACT) is an emerging soft-tissue imaging modality that has great potential for a wide range of biomedical imaging applications. It can be viewed as a hybrid imaging modality that combines an optical contrast mechanism with ultrasonic detection principles, thereby combining the advantages of optical and ultrasonic imaging while circumventing their primary limitations.

Conventional PACT image reconstruction methods assume that the object and surrounding medium are described by a constant speed-of-sound (SOS) value. In order to accurately recover fine structures, SOS heterogeneities should be quantified and compensated for during PACT reconstruction. To achieve this, several groups have proposed hybrid systems that combine PACT with ultrasound computed tomography (USCT). In such systems, a SOS map is reconstructed first via USCT and subsequently employed to inform the PACT reconstruction method. Additionally, the SOS map can provide structural information regarding tissue that complementary to the functional information provided by PACT.

In this talk, we review recent advancements in practical image reconstruction approaches for PACT. Such advancements include physics-based models of the measurement process and associated inversion methods for reconstructing images from limited data sets in acoustically heterogeneous media. We also propose a paradigm shift in the way that images are reconstructed in hybrid PACT-USCT imaging. Namely, we propose to jointly reconstruct the absorbed optical energy density and SOS distributions from a combined set of USCT and PACT measurements, thereby reducing the two reconstruction problems into one. Applications of PACT to transcranial brain imaging and breast cancer detection will also be addressed.

9419-7, Session 2

Feasibility study of robotically tracked photoacoustic computed tomography

Haichong K. Zhang, Kyoto Univ. Graduate School of Medicine (Japan); Hyun Jae Kang, Johns Hopkins Univ. (United States); Emad M. Boctor, Johns Hopkins Outpatient Ctr. (United States)

Photoacoustic imaging (PA) is becoming a promising modality for pre-clinical and clinical application by providing functional information with high penetration depth. In particular, PA computed tomography (PACT) aims to visualize the photoacoustic source distribution by scanning ultrasound transducers around a surface of the structure. Placing transducers around the subject or rotating the subject with fixing transducer position are two major approaches to scan in circular arc trajectory, but both are not flexible and have their drawbacks. To resolve the problem, we propose a new scanning method based on robotic tracking technique. High flexibility of the scanning geometry is available because the trajectory of the tracked transducer generated by robot motion will be regarded as the scanning path. A simulation study of proposed method is conducted, assuming an array ultrasound transducer was used as receivers. To replicate the scenario that the probe is moved by robot, the probe is placed at two positions across 60 degree, and received signals at both positions are used to generate an image. Compared to the result without robot motion, the lateral resolution of the target drastically improved due to aperture extension. In addition, the effect of tracking error was evaluated by providing 500 μm displacement. The contrast variations were compared to the ground truth, and they decreased 3%, 12.25%, and 5.6% by applying displacement in lateral direction, axial direction, and both directions, respectively. This result indicates that the effect of uncertainty in this level is durable, and the feasibility for practical implementation was demonstrated.

9419-8, Session 2

Opto-acoustic image fusion technology for diagnostic breast imaging in a feasibility study

Jason Zalev, Bryan Clingman, Phil Lavin, Don Herzog, Thomas Miller, Michael Ulissey, A. Thomas Stavros, Seno Medical Instruments, Inc. (United States); Alexander A. Oraevsky, TomoWave Laboratories, Inc. (United States); Kenneth Kist, N. Carol Dornbluth, Pamela M. Otto, The Univ. of Texas Health Science Ctr. at San Antonio (United States)

Background

Functional opto-acoustic (OA) imaging is fused with grey scale ultrasound acquired using a specialized duplex handheld probe. Feasibility Study findings indicated potential for higher accuracy for diagnostic breast imaging than conventional diagnostic ultrasound (CDU). A follow-up Pivotal Study is now in progress to demonstrate the improved performance.

Methods

In the Feasibility Study, OA images and videos of 74 breast masses were collected from subjects scanned with the investigational Imagio® breast imaging system. All masses were first detected by CDU and classified according to the BI-RADS system. Histology from image guided needle or surgical biopsy served as gold-standard. Imagery was analyzed by five independent breast radiologists who were blinded to clinical findings and biopsy results and assigned BI-RADS classification and probability-of-malignancy scores to each modality.

Results

When assessed with Imagio, all 34/34 (100%) true positive masses (by biopsy) remained at original BIRADS 4a, 4b, 4c or 5 classifications. For the 40 true negatives (by biopsy), downgrades to BIRADS 3 were achieved for 15/35 (43%) of BIRADS 4a/4b; and 5/5 (100%) of BIRADS 3 masses remained BIRADS 3. The Imagio sensitivity was not significantly different from CDU, suggesting the fused modality will not lead to missed cancers. The absolute improvement of specificity for Imagio was 8% (from 16% to 24%) and the relative improvement was 43%.

Conclusions

If the Feasibility Study trend carries over to Pivotal Study, fused OA imaging could potentially obviate negative biopsies in a large percentage of masses currently classified as BIRADS 4a or 4b without missing cancers.

9419-9, Session 2

Design and manufacturing of scanning probe acoustic microscope test phantom

Xiaohui Chen, Xiaoyue Fang, Jitao Song, Mingyue Ding, Huazhong Univ. of Science and Technology (China)

Scanning probe acoustic microscope(SPAM) can be used to acquire non-destructive internal structures acoustic image as well as the morphology images. However, during the process of imaging, the ultrasonic internal resolution and detectable depth of SPAM are usually unknown. In this paper, we designed two specific specimens(designed test phantom and raw test phantom) as the gold standard to measure the ultrasonic internal resolution of the SPAM. First, the two different phantoms were designed and processed?the designed test phantom contained gold nanoparticles buried deep beneath a polymer cover layer and was manufactured by dispersing the colloidal gold nanoparticles on a silicon substrate with a thickness of 100 um coated with poly(2-vinylpyridine)(PVP) while the raw test phantom did not contain any gold nanoparticle. Then, a series of the acoustic images and morphology images were collected by scanning the designed test phantom and the raw test phantom, respectively. Finally, the designed test phantom was utilized to measure the ultrasonic internal resolution of the SPAM, formed the gold standard calibrator. The experimental results showed some black holes can be observed on the acoustic images by scanning the designed test phantom while no similar structures were observed by scanning the raw test phantom, which further illustrated that the black holes in acoustic image had no corresponding details in the corresponding positions of the morphology image and the same phenomenon can also be observed with the movement of samples. It concluded that the ultrasonic internal resolution of SPAM is less than 50 um and the sound waves can penetrate the silicon substrate with the thickness of 100 um. The proposed method can be used for obtaining the internal information of the sample and further developed as an effective tool for measuring the ultrasonic internal resolution of the SPAM, and making the image of embedded or buried substructures can also be used in biology or other materials possible.

9419-10, Session 2

The study of photoacoustic imaging without nanoparticles as a contrast agent for anti-body drug monitoring

Seung Hee Han, Sogang Univ. (Korea, Republic of) and Univ. of Toronto (Canada) and Univ. Health Network (Canada); Jeeun Kang, Sogang Univ. (Korea, Republic of); Brian C. Wilson, Univ. Health Network (Canada) and Univ. of Toronto (Canada); Tai Kyong Song, Sogang Univ. (Korea, Republic of); Young Il Kim, Seoul National Univ. College of Medicine (Korea, Republic of)

As an emerging hybrid Optical Imaging technique, Photoacoustic Imaging (PAI) became a powerful tool that can scan any disease at the deeper site in tissue and monitor of drug delivery in vivo.(1)(2) Most of PAI system use a nanoparticle as a contrast agent to enhance the PA signal in deeper site in tissue. So this makes PAI's application have some limitation for monitoring of all kinds of anti-body drug, because of various anti-body's absorption excitation. In this study, we designed a PAI system with a tunable pulse OPO laser in which can excite from 450~700nm wavelength to show the optimal wavelength for monitoring of the antibody drug; doxorubicin having peak absorption at near 500nm excitation without any nano-particle combine.(3) We made a gelatin phantoms in which there was 4 different concentration doxorubicin as an anti-body drug; Doxorubicin concentration were in-0mg/ml, 0.5mg/ml, 1mg/ml, 2mg/ml. We did scan the phantom without Doxorubicin from 450~700nm, and then scanned the 3 different phantoms in 50nm step. We found that 500nm is optimization wavelength to excite the doxorubicin to produce PA signal. Except for one phantom without doxorubicin, all 3 phantoms have the maximum peak of PA signal intensity at 500nm excitation. And we found that the PA signal intensity is increasing as the density of Doxorubicin increase. And this result is same with the PA imaging results.

In conclusion we showed that PAI can monitor of anti-body drug; doxorubicin without combine any nano-particle from 450nm to 700nm excitation wavelength. We could show that PAI system can be used for study of anti-body drug monitoring and of cancer therapy monitoring in vivo, if the excitation wavelength of PAI system can be tunable related with the target's absorption in the more wide range.

9419-11, Session 3

Breast ultrasound computed tomography using waveform inversion with source encoding

Kun Wang, Thomas P. Matthews, Fatima Anis, Washington Univ. in St. Louis (United States); Cuiping Li, Delphinus Medical Technologies (United States); Neb Duric, Delphinus Medical Technologies (United States) and Karmanos Cancer Institute (United States); Mark A. Anastasio, Washington Univ. in St. Louis (United States)

Ultrasound computed tomography (USCT) holds great promise for improving the detection and management of breast cancer. Because they are based on the acoustic wave equation, waveform inversion-based reconstruction methods can produce images that possess improved spatial resolution properties over those produced by ray-based methods. However, waveform inversion methods are computationally demanding and have not been applied widely in USCT breast imaging. A computationally efficient numerical wave equation solver has been reported based on a modified Fresnel propagation, which only applies to USCT systems with a planar incident wave. For breast imaging systems with a spherical incident wave, waveform inversion-based reconstruction methods remain computationally challenging.

In this work, source encoding concepts are employed to develop an

accelerated USCT reconstruction method that circumvents the large computational burden of conventional waveform inversion methods. This method, referred to as the waveform inversion with source encoding (WISE) method, encodes the measurement data using a random encoding vector and determines an estimate of the speed-of-sound distribution by solving a stochastic optimization problem by use of a stochastic gradient descent algorithm. For practical applications, a data-filling strategy is proposed to mitigate source inferences to its neighbor receivers. Computer-simulation and experimental phantom studies are conducted to demonstrate the use of the WISE method. Using a single graphics processing unit card, each iteration can be completed within 25 seconds for a 128x128 mm2 reconstruction region. The results suggest that the WISE method maintains the high spatial resolution of waveform inversion methods while significantly reducing the computational burden.

9419-12, Session 3

High-resolution quantitative whole-breast ultrasound: in vivo application using frequency-domain waveform tomography

Gursharan S. Sandhu, Wayne State Univ. (United States); Cuiping Li, Olivier Roy, Delphinus Medical Technologies (United States) and Wayne State Univ. (United States); Neb Duric, Delphinus Medical Technologies (United States) and Karmanos Cancer Institute (United States); Steven Schmidt, Delphinus Medical Technologies (United States) and Wayne State Univ. (United States)

Ultrasound tomography is a promising modality for breast imaging. Many current ultrasound tomography imaging algorithms are based on ray theory and assume a homogeneous background which is inaccurate for complex heterogeneous regions. They fail when the size of lesions are about the same size or smaller than the wavelength of ultrasound used. Therefore, in order to accurately image small lesions, wave theory must be used in ultrasound imaging algorithms to properly handle the heterogeneous nature of breast tissue and the diffraction effects that it induces. Using frequency-domain ultrasound waveform tomography, we present sound speed reconstructions of both phantom and in vivo patient data sets. The improvements in contrast and resolution made upon the previous ray-based methods are dramatic. Where it was difficult to differentiate a high sound speed tumor from bulk parenchyma using ray-based methods, waveform tomography improves the shape and margins of a tumor to easily differentiate it from the bulk breast tissue. Waveform tomography is capable of finding lesions in very dense tissues, a difficult environment for existing ultrasound algorithms as well as mammography. By comparing the sound speed images produced by waveform tomography to MRI, we see that the complex structures in waveform tomography are consistent with those in MRI.

9419-13, Session 3

GPU-based 3D SAFT reconstruction including attenuation correction

Ernst Kretzek, Torsten Hopp, Nicole V. Ruiter, Karlsruher Institut für Technologie (Germany)

3D Ultrasound Computer Tomography (3D USCT) promises reproducible high-resolution images for early detection of breast tumors. The KIT prototype provides three different modalities: reflectivity, speed of sound, and attenuation (ATT). For high resolution and homogeneously illuminated reflectivity images ATT correction is necessary. In this paper we present the ATT correction for 3D USCT and evaluate the method by means of the image quality metrics: absolute error, contrast and homogeneous spatial reflectivity. Due to increase of noise by ATT correction a threshold for ATT correction was introduced to preserve a high contrast. A simulation was used for analysis of the image quality. Furthermore the results were evaluated with real experiment data. The used synthetic aperture focusing technique (SAFT) reconstruction algorithm is highly compute-intensive therefore the ATT correction was optimized for GPUs and integrated into the SAFT algorithm. By using the ATT correction the homogeneity of spatial reflectivity could be improved by 25% and the contrast could be increased by factor 2.8 for in-vivo data.

9419-14, Session 3

Bent ray ultrasound tomography reconstruction using virtual receivers for reducing time cost

Xiaolei Qu, Takashi Azuma, Hirofumi Nakamura, Haruka Imoto, The Univ. of Tokyo (Japan); Satoshi Tamano, Tohoku Univ. (Japan); Shu Takagi, The Univ. of Tokyo (Japan); Shin-Ichiro Umemura, Tohoku Univ. (Japan); Ichiro Sakuma, Yoichiro Matsumoto, The Univ. of Tokyo (Japan)

Bent ray ultrasound sound speed tomography reconstruction can improve image quality comparing to straight ray. However, it suffers from time consuming ray linking, which finds bent ray to link a pair of given emitter and receiver. Currently, multi ray tracing always be required for single ray linking, but all of traced rays will be discarded excepting one which links the given emitter and receiver. It is important for reducing time cost to avoid the discarding and decrease ray tracing number. For this purpose, a novel bent ray reconstruction method (BRRM) using virtual receiver was proposed in this study. Single reconstruction iteration of proposed method includes five steps. Firstly, travel time difference map (TTDM) is picked by first peak method. Secondly, launch angles for straight rays are obtained. Thirdly, ray tracing for each obtained launch angle is implemented and their arrival positions in transducer ring are recorded. Fourthly, TTDM for virtual receivers, which are placed in each bent ray arrival position, is estimated by interpolation of picked TTDM. Fifthly, simultaneous algebraic reconstruction technique (SART) is employed for reconstruction. To evaluated proposed method, ultrasound tomography RF data of simple and complex sound speed models are simulated by PZFlex. Reconstruction results show that proposed method can reduce ray tracing number to be about 20% and time cost to be one third of previous BRRM with similar image quality. In this study, a novel BRRM using virtual receiver is proposed to reduce ray tracing number and time cost of BRRM without image quality decreasing.

9419-15, Session 3

Whole breast tissue characterization with ultrasound tomography

Neb Duric, Peter J. Littrup, Olivier Roy, Steven Schmidt, Delphinus Medical Technologies (United States) and Karmanos Cancer Institute (United States); Veerendra Allada, Delphinus Medical Technologies (United States); Cuiping Li, Delphinus Medical Technologies (United States) and Karmanos Cancer Institute (United States); John Seamans, Delphinus Medical Technologies (United States); Lisa Bey-Knight, Karmanos Cancer Institute (United States)

Through-transmission ultrasound provides quantitative information about tissue properties. We present results from experimental data acquired with SoftVue, a whole-breast ultrasound imaging device that utilizes a ring transducer to generate tomographic data. In the initial experiments with an anthropomorphic phantom, it is shown that speed of sound and attenuation data can be combined to provide imaging information that correlates with tissue stiffness. Image stacks of sound speed and attenuation were mathematically combined to provide a single resulting stack that was then rendered in color to provide visual assessment of the resulting parameter.

The stack of colorized images was overlaid on the corresponding stack of SoftVue B-mode images. The resulting image set was visually assessed for correlations between the rendered colors and the known stiffness properties of the phantom and its inclusions. A qualitative correspondence was found whereby the stiffest masses in the phantom were rendered red and the softest ones blue. The correlation held for two sets of inclusions ranging in size from 8 to 12 mm. To test the feasibility of a similar assessment for in-vivo tissue, we applied the same methodology to the clinical data. Representative cases chosen for the study include the most common benign (cysts and fibroadenomas) and malignant masses (invasive ductal carcinoma), which spanned a variety of breast densities and sizes. Standard clinical imaging was used to assess qualitative tissue characteristics. The colorized image stack was compared against the "clinical truth" (i.e., biopsy results or definitive cyst characterization by imaging) to determine imaging correlates. As in the phantom case, correlations were found with fatty vs dense tissues and with soft vs stiff masses (e.g. benign versus cancers).

Ongoing research is focused on validating and quantifying these findings in a larger sample of study participants and assessing the use of this methodology to differentiate benign masses from cancer.

9419-16, Session 4

Implementation of swept synthetic aperture imaging

Nick Bottenus, Marko Jakovljevic, Duke Univ. (United States); Emad M. Boctor, Johns Hopkins Univ. (United States); Gregg E. Trahey, Duke Univ. (United States)

Despite advances in component quality, beamforming strategies and post-processing techniques, ultrasound image quality is fundamentally limited by the resolution of the system as determined in part by the size of the physical transducer aperture. There is a great expense in increasing the size of transducers and further complication in finding a geometry that is practical for scanning patients. We propose a new technique using a mechanically-swept, position-tracked volumetric transducer in combination with adaptive synthetic aperture beamforming to form large effective apertures. By coherently combining data acquired from multiple aperture positions, a larger region of k-space is interrogated and both the lateral and elevation resolutions can be increased. We demonstrate feasibility of the technique and examine the gains made in the presence of clutter generated by ex vivo tissue layers as a function of effective aperture size. 2-D and 3-D transducer motions are demonstrated using preprogrammed sequences on a translation and rotation stage. Image degradation due to aberration and tissue motion are analyzed and considerations to be made for in vivo imaging are presented.

9419-17, Session 4

In vivo real-time volumetric synthetic aperture ultrasound imaging

Hamed Bouzari, Jørgen A. Jensen, Morten F. Rasmussen, Technical Univ. of Denmark (Denmark); Svetoslav I. Nikolov, BK Medical (Denmark); Andreas H. Brandt, Copenhagen Univ. Hospital Rigshopitalet (Denmark); Matthias B. Stuart, Technical Univ. of Denmark (Denmark)

The synthetic aperture (SA) imaging technique can be used to achieve real-time volumetric ultrasound imaging using 2-D phased array transducer. The sensitivity of SA imaging can be improved by maximizing the acoustic output, but one must consider the limitations of an ultrasound system, both technical and biological. The objective of this paper is to investigate the in vivo applicability and sensitivity of volumetric SA imaging. Utilizing the transmit events to generate a set of virtual point sources, a frame rate of 25 Hz for a 90?90 degrees field-of-view was achieved. Data was obtained using a 3.5 MHz 32?32 elements 2-D phased array transducer connected to an experimental scanner. Proper scaling has been applied to the excitation

signal so that the intensity level complies with the U.S. Food and Drug Administration (FDA) regulations for in vivo ultrasound imaging. A human kidney was volumetrically imaged with SA and parallel beamforming (PB) techniques. We consulted a couple of radiologists for evaluation of volumetric SA by means of a questionnaire. We compared SA against PB in terms of the pathological features presented in the in vivo data. Based on the feedback from domain experts, the results indicate that SA imaging technique volumetrically visualize internal body structures with a better resolution comparing to PB. A novel ultrasound data visualization method to provide the 3-D representations of the anatomy, becomes very beneficial in clinical studies.

9419-18, Session 4

Spatio-temporally smoothed coherence weighting combined with Forward-Backward minimum variance for ultrasound imaging

Xu Li, Huazhong Univ. of Science and Technology (China)

In this paper, the spatio-temporally smoothed coherence weighting method (StS-CF) is combined with the forward-backward minimum variance (FBMV) to improve the medical ultrasound image quality. StS-CF was proposed in our previous work to provide images with increased overall brightness, reduced speckle variance and no black-region artifacts in the area around hyperechoic reflectors. Minimum variance (MV) beamformer can improve the image quality in terms of resolution by suppressing off-axis signals, while keeping on-axis ones. FBMV applies a more accurate estimation of the array covariance matrix, resulting in higher image resolution and contrast. The combined method is tested with simulated RF data, and the results show increased resolution and higher contrast.

9419-19, Session 4

Synthetic aperture imaging using a semi-analytic model for the transmit beams

Jens Munk Hansen, Svetoslav I. Nikolov, BK Medical (Denmark)

Many modern high-end scanners use some form for coherent synthesis of image lines by combining beams acquired with different transmissions, such as retrospective dynamic transmit focusing (Acuson / Siemens), nSIGHT (Philips), Zone imaging (Zonare). There are two major strategies described in literature to calculate the delays - using virtual sources, and using spatial matched filtration. The virtual source model is precise when the

transmit is either strongly focused (f/number ~1, 2) or not focused at all. The spatial matched filtration can be used also with weakly focused transmissions, but requires the measurement and storage of the response of point targets within the limits of the transmit beam.

This paper presents a semi-analytic model for the transmitted field, which can be applied to synthetic transmit imaging. The model is more precise than the virtual sources concept, does not require the measurement of the transmit field as matched filtration methods do, and can be applied both for strongly and weakly focused transmissions. Furthermore the model is applicable for tissue harmonic and contrast enhanced ultrasound imaging.

The paper presents the development of the model using the principles of diffraction, and its validation using computer simulations and measurements on a phantom.

9419-20, Session 4

Synthetic aperture ultrasound imaging with robotic aperture extension

Haichong K. Zhang, Kyoto Univ. Graduate School of Medicine (Japan); Ezgi Ergun, Johns Hopkins Univ. (United States); Gregg E. Trahey, Duke Univ. (United States); Emad M. Boctor, Johns Hopkins Outpatient Ctr. (United States)

Synthetic aperture (SA) is a technique that increases the image resolution by synthetizing information from multiple apertures. The application of this technique for ultrasound imaging has been actively researched. The resolution improvement in SA is limited by the physical size of the ultrasound array transducer, since it is not possible to extend the aperture beyond the size of the transducer array. Consequently, it is hard to achieve high resolution at deep regions because of the large F number. In this paper, we propose a method to extend the available aperture size for SA by sweeping the ultrasound transducer using a robotic arm. Locational information of the probe is used to synthesize the signals received at different positions, therefore the available aperture is wider than the size of transducer. To experimentally validate this approach, a robot arm (UR5, Universal Robot) was used to hold the ultrasound transducer and apply in-plain lateral translational motion. When 64 elements (9.6 mm) in the transducer were used to receive signals, the aperture size was extended to 96 elements (14.4 mm) through robotic movement. An ultrasound phantom with point targets was imaged, and the full width at half maximum (FWHM) of points were measured. As a result, FWHMs at 42 mm and 54 mm depth for conventional synthetic aperture versus the proposed method were 2.49 mm and 3.06 mm versus 2.20 mm and 2.48 mm, respectively.

9419-21, Session 4

Wireless communication of real-time ultrasound data and control

Richard J. Tobias, Cephasonics (United States)

The Internet of Things (IoT) is expected to grow to 26 billion connected devices by 2020 (Gartner), plus the PC/smartphone/tablet segment that includes mobile Health (mHealth) connected devices is projected to account for another 7.3 billion units by 2020. This paper explores some of the real-time constraints on the data-flow and control of a wireless connected ultrasound machine. The paper will define an ultrasound server and the capabilities necessary for real-time use of the device.

The concept of an ultrasound server wirelessly (or over any network) connected to multiple lightweight clients on devices like an iPAD-, iPhone-, or Android-based tablet/smartphone and other network-attached displays (i.e., Google Glass) is explored. Latency in the ultrasound data stream is one of the key areas to measure and to focus on keeping as small as possible (< 30ms) so that the ultrasound operator can see what is at the probe at that moment, instead of where the probe was a short period earlier. By keeping the latency less than 30ms, the operator will feel like the data he sees on the wireless connected devices is running in real-time with the operator.

The second parameter is the management of bandwidth. At minimum we need to be able to see 20 frames-per-second. It is possible to achieve ultrasound in triplex mode at >20 frames-per-second on a properly configured wireless network.

The ultrasound server needs to be designed to accept multiple ultrasound data clients and multiple control clients. A description of the server and some of its key features will be described.

9419-22, Session 5

Dual robotic arm ultrasound tomography: system setup and preliminary tomographic reconstruction

Fereshteh Aalamifar, Dengrong Jiang, Haichong K. Zhang, Alexis Cheng, Xiaoyu Guo, Rishabh Khurana, Iulian I. Iordachita, Johns Hopkins Univ. (United States); Emad M. Boctor, Johns Hopkins Outpatient Ctr. (United States)

Ultrasound tomography enables quantitative measurement of acoustic properties. Robot assisted ultrasound (US) tomography system provides accurate alignment of two US probes. The alignment is done automatically by the robotic arm so that tomographic reconstruction of more anatomies becomes possible. In this study, we propose a new system setup for robot assistance in US tomographic imaging. This setup includes two robotic arms holding two US probes. One of the robotic arms is operated by the sonographer to determine the desired location for the tomographic imaging; this probe can also provide the B-mode US image during the search. The other robotic arm can then align itself with the co-operated US probe. One of the probes will act as transmitter and the other one as receiver to enable tomographic imaging. We provide an overview of the system setup and components together with the calibration procedures. We also provide a preliminary tomographic reconstruction algorithm in an attempt to provide a complete framework for the tomography system. The calibrations as well as the preliminary tomographic reconstruction results show the feasibility of such system; however, more accurate calibrations are required and more variety of tomographic reconstruction algorithms may be tested.

9419-23, Session 5

Preliminary work on the construction of 3D ultrasound computer tomography system

Xu Li, Huazhong Univ. of Science and Technology (China)

Ultrasonic computed tomography (UCT) is a full digital imaging technique, which consists in numerically solving the inverse scattering problem associated to the forward scattering problem describing the interaction of ultrasonic waves with inhomogeneous media. This paper presents a preliminary work on the construction of the UCT system. Two 128-elements linear array transducers were placed on the opposite side of the imaging target, one to transmit the ultrasonic plane wave pulse at a frequency of 2.5MHz and another acts as the receiver. All the received signals were transmitted into the National Instrument (NI) capture system for real-time buffer storage. In this paper, we also give the reconstruction results of ultrasound diffraction tomography based on the simulated data.

9419-24, Session 5

Transducer elements position calibration in a ring array USCT system

Satoshi Tamano, Tohoku Univ. (Japan); Takashi Azuma, Haruka Imoto, Shu Takagi, The Univ. of Tokyo (Japan); Shin-ichiro Umemura, Tohoku Univ. (Japan); Yoichiro Matsumoto, The Univ. of Tokyo (Japan)

In this work, development of Ultrasound Computed Tomography (USCT) transducer elements position calibration method was described. Our groups are under studying USCT experiment system development and image reconstruction aiming at the breast diagnostic imaging by USCT, coexistence of HIFU therapy and therapeutic monitoring. USCT experimental system having 1024 ring array transducer elements, diameter of 104.5mm, electronic High Voltage multiplexer circuits and commercially available ultrasound research platform was used. Full 360-degree circumference is divided into four parts, transducer blocks in the USCT system is composed of 90-degree

respectively was newly developed. The Transducer of each block are consists of center frequency 1.75MHz, -6dB Tx/Rx Band Width 66%. In this system, transducer is divided into four blocks and each block was not able to be combined correctly, that caused the phase difference of up to one wavelength at the joints between the blocks, and is an obstacle to precise image reconstruction has been found. Therefore, in order to reconstruct a precise image, transducer element position calibration method was considered. Ultrasonic transmission was carried out at 2.5MHz. The result of applying the transducer elements position calibration to the received data, -6dB Tx/Rx beam width was 1.71mm for uncorrected, 0.63mm for corrected. Corrected value was almost same as Tx wave length. As a result, when reconstructing cross-sectional images in the present experimental system, expected a precise image, not only reflection black-and-white image but also sound-of-speed transmission image would be reconstructed.

9419-25, Session 5

Registration of 3D ultrasound computer tomography and MRI for evaluation of tissue correspondences

Torsten Hopp, Robin Dapp, Michael Zapf, Ernst Kretzek, Hartmut E. Gemmeke, Nicole V. Ruiter, Karlsruher Institut für Technologie (Germany)

3D Ultrasound Computer Tomography (USCT) is a new imaging method for breast cancer diagnosis. In the current development state it is essential to correlate USCT with a known imaging modality like MRI to evaluate how different tissue types are depicted. However, due to different imaging conditions, e.g. with the breast subject to buoyancy in USCT, a manual correlation is demanding. We present a 3D image registration method to reduce positioning differences and allow direct side-by-side comparison of USCT and MRI volumes. It is based on a two-step approach including a buoyancy simulation with a biomechanical model and freeform deformations using cubic B-Splines for a surface refinement. Simulation parameters are optimized patient-specifically in a simulated annealing scheme. The method was evaluated with in-vivo datasets resulting in an average registration error below 5 mm. Correlating tissue structures can thereby be located in the same or nearby slices in both modalities and three-dimensional non-linear deformations due to the buoyancy are reduced. Image fusion of MRI volumes and USCT sound speed volumes was performed for intuitive display. By applying the registration to data of our first in-vivo study with the KIT 3D USCT, we could confirm several tissue correspondences and learn how connective tissue, carcinomas and breast implants observed in the MRI are depicted in the USCT imaging modes.

9419-26, Session 5

Comparison of breast density measurements made using ultrasound tomography and mammography

Mark A. Sak, Karmanos Cancer Institute (United States); Neb Duric, Peter J. Littrup, Karmanos Cancer Institute (United States) and Delphinus Medical Technologies (United States); Lisa Bey-Knight, Mark Krycia, Karmanos Cancer Institute (United States); Mark E. Sherman, National Cancer Institute (United States); Michael Boone, Alexandra Ethier, Delphinus Medical Technologies (United States); Norman F. Boyd, Princess Margaret Hospital (Canada); Gretchen Gierach, National Cancer Institute (United States)

Women with elevated mammographic percent density, defined as the ratio of fibroglandular tissue area to total breast area on a mammogram are at an increased risk of developing breast cancer. Ultrasound tomography (UST) is an imaging modality that can create tomographic sound speed images of the patient's breast. These sound speed images are useful because breast density is directly proportional to sound speed. The work presented here updates previous results that compared mammographic breast density measurements with UST breast density measurements within an ongoing study. The current analysis has been expanded to include 135 women with negative mammographic screens who then underwent a breast UST scan. Breast density was measured for both imaging modalities and preliminary analysis demonstrated strong and positive correlations (Spearman correlation coefficient rs = 0.70). Additional mammographic and UST related imaging characteristics were also analyzed and used to compare the behavior of both imaging modalities. Preliminary analysis shows that UST can be used as a safe and quantitative marker of breast density that can avert shortcomings of mammography.

9419-27, Session 6

Respiration induced fiducial motion tracking in ultrasound using an extended SFA approach

Kunlin Cao, GE Global Research (United States); Bryan Bednarz, Univ. of Wisconsin School of Medicine and Public Health (United States); L. Scott Smith, Thomas K. F. Foo, Kedar A. Patwardhan, GE Global Research (United States)

Radiation therapy (RT) plays an essential role in the management of cancers. The precision of the treatment delivery process in chest and abdominal cancers is often impeded by respiration induced tumor positional variations, which are accounted for by using larger therapeutic margins around the tumor volume leading to sub-optimal treatment deliveries and risk to healthy tissue. Real-time tracking of tumor motion during RT will help reduce unnecessary margin area and benefit cancer patients by allowing the treatment volume to closely match the positional variation of the tumor volume over time. In this work, we propose a fast approach which enables transferring the pre-estimated target (e.g. tumor) motion extracted from ultrasound (US) image sequences in training stage (e.g. before RT) to online data in real-time (e.g. acquired during RT). The method is based on extracting feature points of the target object, exploiting low-dimensional description of the feature motion through slow feature analysis, and finding the most similar image frame from training data for estimating current/online object location. The approach is evaluated on two 2D+time and one 3D+time US acquisitions. The locations of six annotated fiducials are used for designing experiments and validating tracking accuracy. The average fiducial distance between expert's annotation and the location extracted from our indexed training frame is 1.9+/-0.5mm. Adding a fast template matching procedure within a small search range reduces the distance to 1.4+/-0.4mm. The tracking time per frame is on the order of millisecond, which is below the frame acquisition time.

9419-28, Session 6

A-scan ultrasound system for real-time puncture safety assessment during percutaneous nephrolithotomy

Pedro L. Rodrigues, ICVS/3B's (Portugal) and Univ. do Minho (Portugal) and Instituto Politécnico do Cávado e do Ave (Portugal); Nuno F. Rodrigues, Univ. do Minho (Portugal) and Instituto Politécnico do Cávado (Portugal) and ICVS/3B's (Portugal); Jaime C. Fonseca, Univ. do Minho (Portugal); Marco A. von Krüger, Wagner C. A. Pereira, Univ. Federal of Rio de Janeiro (Brazil); João L. Vilaça, Politécnico do Cávado e do Ave (Portugal) and ICVS/3B's (Portugal)

Background: Kidney stone is a major universal health problem, affecting 10% of the population worldwide. Percutaneous nephrolithotomy is a first-line and established procedure for disintegration and removal of renal stones. Its surgical success depends on the precise needle puncture of renal calyces, which remains the most challenging task for surgeons. This work describes and tests a new ultrasound based system to alert the surgeon when undesirable anatomical structures are in between the puncture path defined through a tracked needle.

Methods: Two circular ultrasound transducers were built with a single 3.3-MHz piezoelectric ceramic PZT SN8, 25.4 mm of radius and resin-epoxy matching and backing layers. One matching layer was designed with a concave curvature to work as an acoustic lens with long focusing. The A-scan signals were filtered and processed to automatically detect reflected echoes.

Results: The transducers were mapped in water tank and tested in a study involving 45 phantoms. These phantoms mimics different needle insertion trajectories with a percutaneous path length between 80 and 150 mm. Results showed that the beam cross-sectional area oscillates around the ceramics radius and it was possible to automatically detect echo signals in phantoms with 120 mm length. No statistical differences were found between the number of echoes and image interfaces identified in ultrasound images.

Conclusions: This new solution may alert the surgeon about anatomical tissues changes during needle insertion, which may decrease the need of X-Ray radiation exposure and ultrasound image evaluation during percutaneous puncture.

9419-29, Session 6

Surveillance of hemodialysis vascular access with ultrasound vector flow imaging

Andreas H. Brandt, Rigshospitalet (Denmark); Jacob B. Olesen, Technical Univ. of Denmark (Denmark); Kristoffer L. Hansen, Marianne Rix, Copenhagen Univ. Hospital Rigshopitalet (Denmark); Jørgen A. Jensen, Technical Univ. of Denmark (Denmark); Michael B. Nielsen, Copenhagen Univ. Hospital Rigshopitalet (Denmark)

Patients dependent on hemodialysis need a well-functioning vascular access, and the vascular access with fewest complications is an arteriovenous fistula (AVF). Dysfunction due to stenosis is a common complication, and regular monitoring of volume flow is recommended to preserve AVF patency. Ultrasound dilation technique (UDT) is considered the gold standard for volume flow surveillance, but the angle independent ultrasound technique Vector Flow Imaging (VFI) has proven to be more precise, when performing single repeated instantaneous measurements. The aim of this study was prospectively to monitor the volume flow in patients with AVF with VFI and compare with UDT values. Three patients with AVF were monitored with UDT and VFI monthly for five months. VFI values were obtained with a commercial ultrasound scanner with a linear transducer and frequency of 9 MHz with integrated VFI. UDT values were obtained with Transonic HD03 Flow-QC Hemodialysis Monitor. Three independent measurements at each scan session were obtained with UDT and VFI each month. Mean volume flow of all patient measurements was 1049 ml/min with UDT and 1017 ml/min with VFI (p= 0.75). The average standard deviation for all patients calculated by the mean standard deviation for each of the individual scan sessions was 128.2 ml/min for UDT and 41.2 ml/min for VFI (p= 0.0650). VFI volume flow values were not significantly different from corresponding estimates obtained with UDT, and VFI measurements were more precise than UDT. The study indicates that VFI can be used for surveillance of volume flow.

9419-30, Session 7

Quantification of cerebral ventricle volume change of preterm neonates using 3D ultrasound images

Yimin Chen, City Univ. of Hong Kong (Hong Kong, China); Jessica Kishimoto, Wu Qiu, Robarts Research Institute (Canada); Sandrine de Ribaupierre, Western Univ. (Canada); Aaron Fenster, Robarts Research Institute (Canada); Bernard Chiu, City Univ. of Hong Kong (Hong Kong, China)

Intraventricular hemorrhage (IVH) is a major cause of brain injury in preterm neonates. Quantitative measurement of ventricular dilation or shrinkage is important for monitoring patients and in evaluation of treatment options. 3D ultrasound (US) has been used to monitor the ventricle volume as a biomarker for ventricular dilation; however, this does not allow for the analysis of localized regions of dilation, which could compress specific white matter bundles and be linked to specific neurological problems later in life. For example, posterior horn enlargement, with thinning of the corpus callosum and parietal white matter fibres, could be linked to poor visuo-spatial abilities seen in hydrocephalic children. In this work, we report on the development and application of a method used to analyze local surface change of the ventricles of preterm neonates with IVH from 3D US images. The technique is evaluated using manual segmentations from 3D US images acquired in two imaging session. The surfaces from baseline and follow-up were rigidly registered and then matched on a point-by-point basis. The distance between each pair of corresponding points served as an estimate of local surface change of the brain ventricle at each vertex. The measurements of local surface change were then superimposed on the ventricle surface to produce the 3D local surface change map that may provide important information on the dilation pattern of brain ventricles following IVH, their response to different treatment options, and potentially to elucidate the deficiencies a patient will have later in life.

9419-31, Session 7

Quantitative ultrasound texture analysis for clinical decision making support

Jie Ying Wu, Brown Univ. (United States); Michael Beland, Joseph Konrad, Rhode Island Hospital (United States); Adam Tuomi, David Glidden, Brown Univ. (United States); David J. Grand, Derek Merck, Rhode Island Hospital (United States)

We propose a general ultrasound (US) texture-analysis and machine-learning framework for detecting the presence of disease that is suitable for clinical application across clinicians, disease types, devices, and operators. Its stages are image selection, image filtering, ROI selection, feature parameterization, and classification. Each stage is modular and can be replaced with alternate methods. Thus, this framework is adaptable to a wide range of tasks.

Our two preliminary clinical targets are hepatic steatosis and adenomyosis diagnosis. For steatosis, we collected US images from 288 patients and their pathology-determined values of steatosis (%) from biopsies. Two radiologists independently reviewed all images and identified the region of interest (ROI) most representative of the hepatic echo-texture for each patient.

To parameterize the images into comparable quantities, we filter the US images at multiple scales for various texture responses. For each response, we collect a histogram of pixel features within the ROI, and parameterize it as a Gaussian function using its mean, standard deviation, kurtosis, and skew to create a 36-feature vector. Our algorithm uses a support vector machine (SVM) for classification. Using a threshold of 10%, we achieved 72.81% overall accuracy, 76.18% sensitivity, and 65.96% specificity in identifying steatosis with leave-ten-out cross-validation (p<0.0001).

Extending this framework to adenomyosis, we identified 38 patients with MR-confirmed findings of adenomyosis and previous US studies and 50 controls. A single rater picked the best US-image and ROI for each case. Using the same processing pipeline, we obtained 76.14% accuracy, 86.00% sensitivity, and 63.16% specificity with leave-one-out cross-validation (p<0.0001).

9419-32, Session 7

Classification of kidney and liver tissue using ultrasound backscatter data

Fereshteh Aalamifar, Johns Hopkins Univ. (United States) and Children's National Health System (United States); Hassan Rivaz, McGill Univ. (Canada); Juan J. Cerrolaza, Children's National Medical Ctr. (United States); James Jago, Philips Healthcare, N.A. (United States); Nabile M. Safdar, Children's National Medical Ctr. (United States); Emad M. Boctor, Johns Hopkins Univ. (United States); Marius G. Linguraru, Children's National Medical Ctr. (United States)

Ultrasound (US) tissue characterization provides valuable information for the initialization of automatic segmentation algorithms, and can further provide complementary information for diagnosis of pathologies. US tissue characterization is challenging due to the presence of various types of image artifacts and dependence on the sonographer's skills. The goal of this work is to classify liver versus kidney tissue in 3D volumetric US data. To this end, we first propose the computation of a large set of features based on the homodyned-K distribution of the speckle as well as the correlation coefficients between small patches in 3D images. We then utilize the random forest framework to select the most important features for classification. Experiments on in-vivo 3D US data from nine pediatric patients with hydronephrosis showed an average accuracy of 94% for the classification of liver and kidney tissues with potential to assist in the classification and segmentation of abdominal soft tissue.

9419-33, Session 7

An integrated framework for spatio-temporal registration of intravascular ultrasound pullbacks

Ling Zhang, The Univ. of Iowa (United States); Andreas Wahle, Zhi Chen, Richard Downe, University of Iowa (United States); John Lopez, Loyola University (United States); Tomas Kovarnik, Charles University (Czech Republic); Milan Sonka, University of Iowa (United States)

Spatial-temporal alignment and circumferential co-registration of baseline and follow-up intravascular ultrasound (IVUS) pullbacks is of paramount importance in studying the progression/regression of coronary artery disease. Automating these two tasks has the potential to increase productivity when studying large patient populations. Current automated methods are often designed for only one of the two tasks – alignment or co-registration. In this paper, we propose an integrated framework which combines the two tasks and employs side-branches to constrain the IVUS pullback alignment and co-registration tasks. For alignment, canonical time warping technique optimizes extracted features and weights cumulative distances. For co-registration, the search range of cross-correlation based method is constrained by utilizing the angular differences between side-branches. Pilot validation is currently available for ten pairs of IVUS pullback sub-sequences. Results show average alignment and co-registration errors of 0.49 mm and 5.56°, respectively, a notable improvement over our previous approach (p < 0.001). Our method has the potential to improve locational correspondence in studies of atherosclerotic vascular disease development using IVUS.

9419-34, Session 7

Iterative motion compensation approach for ultrasonic thermal imaging

Ioana N. Fleming, Gregory D. Hager, Xiaoyu Guo, Hyun Jae Kang, Johns Hopkins Univ. (United States); Emad M. Boctor, Johns Hopkins Medical Institutions (United States)

As thermal imaging attempts to estimate very small tissue motion (on the order of tens of microns), it can be negatively influenced by signal decorrelation. Patient's breathing and cardiac cycle generate shifts in the RF signal patterns. Other sources of movement could be found outside the patient's body, like transducer slippage or small vibrations due to environment factors like electronic noise. Here, we build upon a robust displacement estimation method for ultrasound elastography and we investigate an iterative motion compensation algorithm, which can detect and remove non-heat induced tissue motion at every step of the ablation procedure. The validation experiments are performed on laboratory induced ablation lesions in ex-vivo tissue. The ultrasound probe is either held by the operator's hand or supported by a robotic arm. We demonstrate the ability to detect and remove non-heat induced tissue motion in both settings. We show that removing extraneous motion helps unmask the effects of heating. Our strain estimation curves closely mirror the temperature changes within the tissue. While previous results in the area of motion compensation were reported for experiments lasting less than 10 seconds, our algorithm was tested on experiments that lasted close to 20 minutes.

9419-35, Session 7

Extraction of four chamber synchronization information from ultrasound images by discrete shape optimization

Yaonan Zhang, Northeastern Univ. (China)

The purpose of this paper is to extract the synchronization information of four cardiac chambers from two-dimensional echocardiography images. Traditionally much research effort has been spent on extracting motion, strain and synchronization information from Ultrasound images for left ventricles. In order to understand the whole mechanical mechanisms of the heart, to measure the electromechanical delay and to quantitatively diagnose the heart functions, the accurate measurement of the global synchronization information of the heart from medical images is necessary. The proposed novel method in this paper consists of several steps: 1) in the first step, an active shape model scheme is used to initially detect the chamber boundaries, and a further refinement is then done based on local image variances; 2) the purpose of this step is to estimate the motions of each pixel along each chamber boundary in the consequent images using an ant colony optimization; 3) this step involves the calculation of the motion magnitude curve of each chamber boundary along heart cycles; the spline fitting of the curves; the synchronization information calculation, e.g. atrium-ventricle systole & diastole delay, left-right ventricle systole & diastole delay and etc. The proposed methods have been tested on many ultrasound image sequences, some of them are simulated images where the accuracy of estimated motion vectors can be easily validated, and some of the experiments are based on real ultrasound images taken from Ultrasound diagnosis machines in hospitals.

9419-36, Session 7

Parametric imaging of tumor perfusion and neovascular morphology using ultrasound

Kenneth Hoyt, The Univ. of Alabama at Birmingham (United States)

In this paper, a novel image processing strategy is detailed for the measurement of tumor perfusion and neovascular morphology parameters from a sequence of dynamic contrast-enhanced ultrasound (DCE-US) images. A computationally efficient technique for locally mapping tumor perfusion parameters using skeletonized neovascular data is also introduced. Longitudinal DCE-US image datasets were collected in breast cancer patients before and after initiation of preoperative (neoadjuvant) chemotherapy. Preliminary findings suggest that breast tumor response to neoadjuvant chemotherapy is characterized in part by considerable changes in intratumoral perfusion parameters. Moreover, our study also revealed that DCE-US-based neovascular morphology parametric measures also exhibit pronounced changes that may be predictive of breast tumor response to systemic treatment as determined from surgical specimens. Breast cancer management from early detection to therapeutic monitoring is currently undergoing profound changes. The development of novel imaging techniques that are sensitive to the unique biological conditions of each individual tumor represent valuable tools in the pursuit of personalize medicine.

9419-37, Session PSMon

Research on respiratory motion correction method based on liver contrast-enhanced ultrasound images of single mode

Ji Zhang, Tao Li, Qiang Shi Zheng, Yong Yi Li, Wuhan General Hospital of Guangzhou Military Command (China)

Abstract Objective To reduce the effects of respiratory motion in the quantitative analysis based on liver contrast-enhanced ultrasound (CEUS) image sequences of single mode. Methods The image gating method and the iterative registration method using model image were adopted to register liver contrast-enhanced ultrasound image sequences of single mode. The feasibility of the proposed respiratory motion correction method was explored preliminarily using 10 hepatocellular carcinomas CEUS cases. The positions of the lesions in the time series of 2D ultrasound images after correction were visually evaluated. Before and after correction, the quality of the weighted sum of transit time (WSTT) parametric images were also compared, in terms of the accuracy and spatial resolution. For the corrected and uncorrected sequences, their mean deviation values (mDVs) of time-intensity curve (TIC) fitting derived from CEUS sequences were measured. Results After the correction, the positions of the lesions in the time series of 2D ultrasound images were almost invariant. In contrast, the lesions in the uncorrected images all shifted noticeably. The quality of the WSTT parametric maps derived from liver CEUS image sequences were improved more greatly. Moreover, the mDVs of TIC fitting derived from CEUS sequences after the correction decreased by an average of 48.48±42.15. Conclusion The proposed correction method could improve the accuracy of quantitative analysis based on liver CEUS image sequences of single mode, which would help in enhancing the differential diagnosis efficiency of liver tumors.

9419-38, Session PSMon

Time-frequency analysis of neonatal cranial ultrasonic movies for selective detection of pulsatile tissues by avoiding probe-motion artifact

Yuki Tabata, Masayuki Fukuzawa, Yusuke Izuwaki, Nobuyuki Nakamori, Kyoto Institute of Technology (Japan); Yoshiki Kitsunezuka, Saiseikai Hyogo-ken Hospital (Japan)

In order to find how to detect the pulsatile tissues in neonatal cranial ultrasonic movies by avoiding probe-motion artifact, a time-frequency analysis has been performed in several movie fragments at typical three scenes: (a) a brain-lost, (b) a brain-captured and probe-swayed, and (c) a brain-captured and probe-stabilized ones. The pulsatile tissue, which is a key point of pediatric diagnosis, had successfully detected fomerly but it required manual extraction of the probe-stabilized scene to avoid probe-motion artifact. In this analysis, the averages of echo intensity and power spectrum were evaluated for every movie fragment according to the DC and a total AC components of a power spectrum which was calculated from a time-variation of 64 samples of echo intensity at each pixel by Fast Fourier Transform. The results revealed that (1) significant low average of echo intensity was found at the brain-lost scene rather than that at the other scenes, and (2) lower average of power spectrum was found at the probe-stabilized scene rather than the probe-swayed ones. This fact strongly suggests that the averages of echo intensity and power spectrum are promising features for automatic extraction of probe-stabilized scenes. It must enable us to detect the pulsatile tissues selectively by avoiding probe-motion artifact and lead into systematic analysis of the whole of our extensive movie archives, which is useful not only for retrospective study of ischemic diseases but also for bedside diagnosis to stabilize the freehand ultrasonic probe.

9419-39, Session PSMon

Ultrasound semi-automated measurement of fetal nuchal translucency thickness based on principal direction estimation

Heechul Yoon, Hyuntaek Lee, Hae-kyung Jung, Samsung Electronics Co., Ltd. (Korea, Republic of); Mi-Young Lee, Hye-Sung Won, Asan Medical Ctr. (Korea, Republic of)

The objective of the paper is to introduce a novel method for nuchal translucency (NT) boundary detection and thickness measurement, which is one of the most significant markers in the early screening of chromosomal defects, namely Down syndrome. To improve the reliability and reproducibility of NT measurements, several automated methods have been introduced. However, the performance of their methods degrades when NT borders are tilted due to varying fetal movements. Therefore, we propose a principal direction estimation based NT measurement method to provide reliable and consistent performance regardless of both fetal positions and NT directions. At first, Radon Transform and cost function are used to estimate the principal direction of NT borders. Then, on the estimated angle bin, i.e., the main direction of NT, gradient based features are employed to find initial NT lines which are beginning points of the active contour fitting method to find real NT borders. Finally, the maximum thickness is measured from distances between the upper and lower border of NT by searching along to the orthogonal lines of main NT direction. To evaluate the performance, 89 of in vivo fetal images were collected and the ground-truth database was measured by clinical experts. Quantitative results using intraclass correlation coefficients and difference analysis verify that the proposed method can improve the reliability and reproducibility in the measurement of maximum NT thickness.

9419-40, Session PSMon

Breast cancer detection based on time reversal and the optical theorem

Edwin A. Marengo, Jing Tu, Northeastern Univ. (United States)

We develop a new wave physics-based approach to detect anomalies in biological tissues such as cancer lesions from active sensing data, with particular emphasis on nonionizing radiation methods such as microwave breast imaging, ultrasound imaging, and diffuse optical tomography. The biological medium surrounding the target of interest, e.g., a tumor, is assumed to be highly nonhomogeneous and reverberating. This implies that there are in general multiple paths for the propagation of wave signals from an interior domain where the target of interest is located to the

sensing aperture where the scattered fields are measured. Two physical concepts are used to exploit this rich multipath environment so as to enhance tumor detection and imaging performance: wave time reversal, and the optical theorem which describes energy conservation in scattering phenomena. Previous related work has reported the use of time reversal for breast cancer detection. We use not only time reversal, but also the optical theorem, and develop novel detection and imaging algorithms based on both. We demonstrate for the particular context of acoustic waves that the derived approaches outperform conventional methods including the energy detector and the recently developed time reversal detector which exploits time reversal but not the optical theorem, as well as beamforming imagers based on time reversal alone.

9419-41, Session PSMon

Breast ultrasound tomography using both transmission and reflection data: initial clinical studies

Lianjie Huang, Youzuo Lin, Ting Chen, Junseob Shin, Miranda H. Intrator, Kenneth Hanson, Los Alamos National Lab. (United States); Katherine Epstein, Daniel Sandoval, Michael Williamson, The Univ. of New Mexico (United States)

Ultrasound tomography has great potential to provide quantitative estimations of mechanical properties of the breast for accurate characterization of breast cancers. We design and manufacture a new synthetic-aperture breast ultrasound tomography system with two parallel transducer arrays. The distance of these two arrays is adjustable for scanning the breasts with different sizes. The transducer arrays are translated vertically to scan the breast from the chest wall/axillary region to the nipple region to acquire ultrasound transmission and reflection data for whole-breast ultrasound tomography imaging. We use the system to acquire patient data at the University of New Mexico Hospital for clinical studies. We employ our recently developed ultrasound bent-ray and waveform tomography methods using both transmission and reflection data for reconstructing sound-speed distributions of the breast. Our initial clinical tomography results demonstrate that our breast ultrasound tomography methods using both transmission and reflection data greatly improve tomographic reconstructions compared to those obtained using only transmission data or only reflection data.

9419-42, Session PSMon

Ultrasound bent-ray tomography with a modified total-variation regularization scheme

Miranda H. Intrator, Los Alamos National Lab. (United States) and Univ. of Colorado Denver School of Medicine (United States); Youzuo Lin, Ting Chen, Junseob Shin, Lianjie Huang, Los Alamos National Lab. (United States)

The sound-speed distribution of the breast can be used for characterizing breast tumors, because they typically have a higher sound-speed than normal breast tissue. Breast sound-speed distribution can be reconstructed using ultrasound tomography. We have recently demonstrated that ultrasound bent-ray tomography, using arrival times of both transmission and reflection data, significantly improves image resolution and image quality. To further improve the robustness of tomographic reconstructions, we develop an ultrasound bent-ray tomography method using a modified total-variation (MTV) regularization scheme. Regularization is often used to solve ill-posed inverse problems, and image reconstruction quality depends heavily on regularization schemes. The most commonly used Tikhonov regularization tends to smooth tomographic images, whereas total-variation (TV) regularization preserves the sharpness of tumor margins at the cost

of increased image noise. Our new ultrasound bent-ray tomography with MTV regularization significantly reduces image noise while maintaining the advantage of TV regularization. We apply our new method to ultrasound transmission and reflection data from numerical and laboratory phantoms, and compare the results with those obtained using Tikhonov and TV regularization schemes.

9419-43, Session PSMon

Design and fabrication of a ring-shaped array for photoacoustic tomography

Chi Tat Chiu, Hyung Ham Kim, The Univ. of Southern California (United States); Xueding Wang, Univ. of Michigan (United States); Koping Kirk Shung, The Univ. of Southern California (United States)

Rheumatoid arthritis has been one of the most common and disabling type of arthritis. The current imaging modalities used nowadays when evaluating arthritis include conventional radiography, magnetic resonance imaging (MRI), ultrasonography, etc. These imaging modalities are playing an important role in providing valuable information for both diagnosis and investigations in finding optimized treatments. However, they also have their limitations, for example, ionizing radiation for radiography, high image acquisition time for MRI, limited spatial resolution for conventional ultrasonography, etc.

Recent works show that photoacoustic tomography (PAT) has the potential to be used for the early diagnosis and monitoring of rheumatoid arthritis. PAT is a hybrid imaging modality which is capable on forming images of which the contract depends on the differences in the optical absorption within the region of interest. Specifically, it is highly sensitive in blood detection as blood contains highly absorbing chromophores. As it is known that angiogenesis and increased vascularity are observed in the early stage of rheumatoid arthritis, using PAT to detect and monitor rheumatoid arthritis is promising.

In this study, the goal is to design and fabricate a ring-shaped array used for PAT. The array would have a diameter large enough to accommodate a human finger so as to image the cross-section of the joint. It should be capable also in performing real-time ultrasonography so as to give additional information in both positioning the array and as an anatomical reference.

9419-44, Session PSMon

Multiwavelength photoacoustic microscopy using a custom developed supercontinuum fiber laser

Esra Aytac-Kipergil, Nasire Uluc, Aytac Demirkiran, Hakan Erkol, Mehmet B. Unlu, Bo?aziçi Univ. (Turkey)

Photoacoustic imaging is based on reconstruction of optical energy deposition that leads to ultrasound signals through thermal expansion. The signal amplitude is directly proportional to the local fluence and the absorption coeffcient of the target; thus, concurrence of source wavelength with the absorption peak of chromophores is of paramount significance. Here, we report a multiwavelength, very fast photoacoustic microscopy system with ultrabroad (500-1300 nm) spectrum. The laser is fiber-integrated, custom developed especially for photoacoustic excitation with adjustable parameters; pulse duration, energy and repetition frequency independent from each other. Pulse repetition frequency could be varied between 50 kHz to 3 MHz by acousto optic modulator through custom-developed field-programmable gate-array electronics. A 3.5 meter long photonic crystal fiber is spliced to double-clad Yb-doped fiber of the laser amplifier for supercontinuum generation. The supercontinuum is sent through an acousto-optic tunable filter that enables very rapid wavelength tuning before being focused into the object. The laser system is superior to laser diodes and tunable Q-Switched lasers in the sense that it can provide

higher pulse energies and higer repetition frequencies with the choice for a desired wavelength in the visible and near infrared spectral region. Multiwavelength imaging is performed on a phantom comprising multiple polymer tubes with diameters varying from 50 μm to 1mm filled with dyes of known absorption spectra. The tubes are immersed in Intralipid solution to mimic strong optical scattering of tissue, then the phantom is scanned along a line of length 50 mm in steps of 10 μm. Taking measurements at multiple wavelengths allows for spectral separation of signals from different absorbers based on their characteristic absorption spectra and enables functional imaging.

9419-45, Session PSMon

Mapping viscoelastic properties by multi-line (ML) acoustic radiation force

Mikako Gomyo, Kyoto Univ. Graduate School of Medicine (Japan); Kengo Kondo, Makoto Yamakawa, Kyoto Univ. (Japan); Tsuyoshi Shiina, Kyoto Univ. Graduate School of Medicine (Japan)

Non-invasive measurement of tissue characterizations, viscosity as well as elasticity, is considered to be important to diagnose some disease in an early stage. The recent study, Shear wave Dispersion Ultrasound Vibrometry (SDUV), has been conducted under in vivo and ex vivo conditions, which could estimate shear modulus and viscosity in a 4 x 4 mm2 area. In this study, multi-line (ML) acoustic radiation force method could map shear modulus and viscosity. ML uses seven focus points in depth to create much planar shear wave than ever, and twenty pushing line to obtain data in 38.4 mm width and 27.4 mm depth area. These sequence contributes to express precise values of shear modulus and viscosity at each pixels. A 10% gelatin phantom with a 10% gelatin and 2% xanthan gum mixture inclusion was prepared for ML experiment, and two homogenous phantoms made of the same concentrations for SDUV experiment to validate. The ML measurement resulted $\mu\_1 = 1.32 \pm 0.74$ kPa, $\mu\_2 = 0.84 \pm 0.56$ Pa·s in 10 % gelatin background, $\mu\_1 = 2.34 \pm 1.41$ kPa, $\mu\_2 = 1.50 \pm 1.61$ Pa·s in 10 % gelatin and mixed inclusion; Their corresponding SDUV measurement were $\mu\_1 = 1.25 \pm 0.45$ kPa, $\mu\_2 = 0.77 \pm 0.41$ Pa·s in 10 % gelatin background, $\mu\_1 = 2.04 \pm 0.73$ kPa, $\mu\_2 = 1.59 \pm 0.97$ Pa·s, respectively. Though further evaluation is required, the results show the feasibility of in vivo and ex vivo effective diagnoses.

9419-46, Session PSMon

A new combined prior based reconstruction method for compressed sensing in 3D ultrasound imaging

Muhammad S. Uddin, Rafiqul Islam, Murat Tahtali, Andrew J. Lambert, Mark R. Pickering, UNSW Canberra (Australia)

Ultrasound (US) imaging is one of the most popular medical imaging modalities and recently 3D US imaging is gaining popularity due to its considerable advantages over 2D US imaging. However, 3D US imaging is limited by the acquisition time and huge amount of data processing. Methods for reducing the scan time and the acquired data for 3D US imaging procedures have attracted considerable research interest. Compressed sensing (CS) is one of the best candidates to accelerate the acquisition rate and reducing the required data processing without degrading the image quality. Nevertheless, it introduces noise-like artefacts due to random under sampling. To address this issue, we propose a combined prior based reconstruction method in which a Gaussian mixture model (GMM) constraint in the wavelet domain is combined with a total variation (TV) constraint for use as a regularisation prior. Experimental evaluation is conducted to validate our method using synthetic 3D US image. The proposed approach performs better than the other approaches in both qualitative and quantitative measures.

9419-47, Session PSMon

Ultrasound coherence imaging using hardware receive beamforming and broad transmit beams

Nick Bottenus, Gregg E. Trahey, Duke Univ. (United States); Kutay F. Ustuner, Siemens Medical Solutions USA, Inc. (United States)

Ultrasonic echoes backscattered from diffuse targets such as tissue exhibit a particular spatial similarity, or coherence, that can be observed using an array transducer. Conventional B-mode ultrasound images suffer from clutter that is composed of reverberation, aberration, and off-axis scattering and exhibits only partial coherence, making it possible to suppress these confounding signals using coherence-based imaging techniques. Coherence can be measured by transmitting a focused wave into the tissue and computing the covariance of the returned echo signals across all combinations of receive channels for each spatial location. We mathematically and empirically prove the equivalence of measuring coherence as a function of transmit channel with that of measuring coherence as a function of receive channel. This equivalence forms the basis for an alternative method for coherence measurement using a synthetic aperture technique to store focused and summed receive channel data as a function of transmit channel. This technique obviates the need for access to individual receive channel data and is compatible with existing delay-and-sum signal pipelines on commercial clinical scanners. We use an ACUSON SC2000™ ultrasound system to acquire data and perform full synthetic aperture focusing at up to 35 frames per second and produce in vivo short-lag spatial coherence images with reduced clutter.

Conference 9420: Digital Pathology

Wednesday - Thursday 25–26 February 2015

Part of Proceedings of SPIE Vol. 9420 Medical Imaging 2015: Digital Pathology

9420-1, Session 1

Twenty years of image-based search technology in review: bright prospects for image-based search and decision support in whole slide imaging *(Keynote Presentation)*

Ulysses J. Balis, Univ. of Michigan Health System (United States)

Whole slide Imaging, as a collection of technologies in varying stages of adoption, will likely reach a critical mass of implementation, when one or more compelling clinical use cases can be realized. Of the numerous envisioned functions served by whole slide imaging, use of spatial information to algorithmically generate diagnostic, prognostic and theranostic information ranks highly, meriting vigorous exploration. A major component of enabling such algorithms is the attainment of robust underlying pattern matching technology, such that for any predicate test image, a candidate cohort of diagnostically correlated images can be identified from a pre-coordinated library of cases. Additionally, in the setting where such digital image libraries are augmented with diagnosis, treatment and outcomes metadata, it becomes possible to generate powerful and predictive decision support tools, which effectively convert a constellation of image-based features to a multivariate, high-dimensional predicate calculus assertion, ultimately imputing one or more diagnostically actionable terms from a controlled vocabulary. This historical review session will explore the current level of capability of the general class of so-called content-based image retrieval, as well as what can be expected in the near term, as a result of continued advances in feature detection / pattern recognition technology. An initial didactic session will be followed by interactive demonstrations, with an emphasis on oncology use-cases.

9420-2, Session 1

Segmentation of digitized histological sections for vasculature quantification in the mouse hind limb

Yiwen Xu, The Univ. of Western Ontario (Canada); J. Geoffery Pickering, Zengxuan Nong, Robarts Research Institute (Canada); Aaron D. Ward, The Univ. of Western Ontario (Canada)

Characteristics of microvasculature can be revealed by immunohistochemical tissue staining, but manual quantification of these characteristics on whole-slide images containing potentially hundreds of vessels on each is tedious and subject to operator variability. Our objective was to develop and validate a fully automated segmentation of the vascular smooth muscle layer on whole-section histology of wild type and regenerated post-ischemia mouse hind limb microvasculature, stained for smooth muscle using 3,3'-Diaminobenzidine (DAB) immunostain. Major challenges to this segmentation are the irregularity of vessel wall staining, resulting in apparent fragmentation of intact vessels on the images, and artefactual appearance of stain on structures other than vessel walls. The automated segmentation localizes these fragments by color deconvolution to isolate the DAB stain. Complete vessel walls were reconstituted by joining of the topological skeletons of the vessel wall fragments. Based on a highly accurate registration of serial histology sections previously developed in our lab, artefactual fragments were removed based on measured incoherence with neighboring tissue in 3D. The vessel wall thickness, and vessel count, density, area, and perimeter were quantified. For segmentation validation, vessels were manually delineated and compared to the automated segmentation approach on a wild type mouse, with a dice similarity

coefficient of 0.84. Differences were observed in the vessel measurements between the wild type and the regenerated vasculature in post-ischemic mice, as expected. Fully automatic and accurate measures of the vascular morphology are feasible with the automated segmentation of the vascular smooth muscle.

9420-3, Session 1

Structure preserving color deconvolution for immunohistochemistry images

Ting Chen, Chukka Srinivas, Ventana Medical Systems, Inc. (United States)

Immunohistochemistry (IHC) staining is an important technique for the detection of one or more biomarkers within a single tissue section. Due to the limitation of the CCD color camera, the acquired RGB image only contains three channels. Therefore, the accurate unmixing of an IHC image into individual constituent dyes for the biomarkers is a much more challenging task than the unmixing of a multi-channel spectral image. To the best of our knowledge, there are not many studies in the literature on IHC image unmixing. The most effective technique thus far is the color deconvolution method proposed by Ruifrok et al.. This technique has been widely used in the image analysis of digital pathology, such as Aperio and ImageJ However, Ruifrok's method independently estimates the individual dye contributions at each pixel which potentially leads to ''holes and cracks'' in the cells in the unmixed images. This is clearly inadequate since strong spatial dependencies exist in the tissue images which contain rich cellular structures.

In this paper, we formulate the unmixing algorithm into a least-square framework of image patches, and propose a novel color deconvolution method which explicitly incorporates the spatial smoothness and structure continuity constraint into a neighborhood graph regularizer. An analytical closed-form solution to the cost function is derived for this algorithm for fast implementation. The algorithm is finally evaluated on a clinical data set containing a number of 3,3'-Diaminobenzidine (DAB) and hematoxylin (HTX) stained IHC slides and demonstrates better unmixing results than the existing strategy.

9420-4, Session 2

Anisotropic Tubular Filtering for Automatic Detection of Acid-Fast Bacilli in Ziehl-Neelsen Stained Sputum Smear Samples

Shan E. A. Raza, The Univ. of Warwick (United Kingdom); M. Qaisar Marjan, Muhammad Arif, Pakistan Institute of Engineering and Applied Sciences (Pakistan); Farhana Butt, Faisal Sultan, Shaukat Khanum Memorial Cancer Hospital & Research Ctr. (Pakistan); Nasir M. Rajpoot, The Univ. of Warwick (United Kingdom) and Qatar Univ. (Qatar)

One of the main factors for high workload in pulmonary pathology in developing countries is the relatively large proportion of tuberculosis (TB) cases which can be detected with high throughput using automated approaches. TB is caused by the bacterium Mycobacterium tuberculosis, which appears as thin, rod-shaped acid-fast bacilli (AFB) in Ziehl-Neelsen (ZN) stained sputum smear samples. In this paper, we present an algorithm for automatic detection of Acid Fast Bacilli (AFB) in ZN stained images of sputum smear samples obtained using a light microscope. A key component of the proposed algorithm is the enhancement of raw input image using

Polar Cosine Transform (PCT) which suppresses the background noise while simultaneously enhancing strong anisotropic features of AFBs present in the image. The resulting image is then segmented using colour features and candidate AFBs are identified. Finally, a support vector machine classifier using morphological features from candidate AFBs decides whether a given image is AFB positive or not. We demonstrate the effectiveness of the proposed anisotropic tubular filtering with two different feature sets by showing that the proposed image analysis pipeline results in higher accuracy and F1-score than the same pipeline with standard median filtering for image enhancement.

9420-5, Session 2

Aging display's effect on interpretation of digital pathology slide

Ali R. N. Avanaki, Kathryn S. Espig, Albert Xthona, Barco, Inc. (United States); Tom Kimpe, Barco N.V. (Belgium)

It is our conjecture that the variability of colors in a pathology image effects the interpretation of pathology cases, whether it is diagnostic accuracy, diagnostic confidence, or workflow efficiency. In this paper, digital pathology images are analyzed to quantify the perceived difference in color that occurs due to display aging, in particular a change in the maximum luminance, white point, and color gamut. The digital pathology images studied include diagnostically important features, such as the conspicuity of nuclei. Three different display aging models are applied to images: aging of luminance & chrominance, aging of chrominance only, and a stabilized luminance & chrominance (i.e., no aging). These display models and images are then used to compare conspicuity of nuclei using CIE ?E2000, a perceptual color difference metric. The effect of display aging using these display models and images is further analyzed through a human reader study designed to quantify the effects from a clinical perspective. The results of this study along with a comparison to simulation results will be included in the full paper.

9420-6, Session 2

An adaptive algorithm for detection of multiple-type, positively stained nuclei in IHC images with minimal prior information: application to OLIG2 staining for gliomas

Hatice Cinar Akakin, Anadolu Univ. (Turkey); Hamza N. Gokozan, Jose J. Otero, Metin N. Gurcan, The Ohio State Univ. (United States)

We propose a method to detect and segment the oligodendrocytes and gliomas in OLIG2 immunoperoxidase stained tissue sections. In general, glioma cells and oligodendrocytes mostly differ in shape and size within the tissue slide. In Olig2 stained tissue images, gliomas are represented with irregularly shaped nuclei with varying sizes and brown shades. On the other hand, oligodendrocytes have more regular round nuclei shapes and smaller in size when compared to glioma cells found in oligodendroglioma, astrocytomas, or oligoastrocytomas. The first task is to detect the OLIG2 positive cell regions within the image. The second task is to segment each cell nucleus and count the number of cell nuclei. However, the cell nuclei belonging to glioma cases have particularly irregular nuclei shapes and form cell clusters by touching or overlapping with each other. In addition to this clustered structure, the shading of the brown stain and the texture of the nuclei differ slightly within a tissue image. The final step of the algorithm is to classify glioma cells versus oligodendrocytes. Our method starts with color segmentation to detect positively stained cells followed by the classification of single individual cells and cell clusters by K-means clustering. Detected cell clusters are segmented with the H-minima based watershed algorithm. The novel aspects of our work are: 1) the detection and segmentation of multiple-type, positively-stained nuclei by incorporating only minimal prior information; and 2) adaptively determining clustering

parameters to adjust to the natural variation in staining as well as the underlying cellular structure while accommodating multiple cell types in the image. Performance of the algorithm to detect individual cells is evaluated by sensitivitiy and precision metrics. Promising results (90% sensitivity and 82% precision) were achieved with a preliminary dataset, including four tissue slides with ground truth markings by two pathologists.

9420-7, Session 2

Characterizing primary refractory neuroblastoma: prediction of outcome by microscopic image analysis

Muhammad Khalid Khan Niazi, The Ohio State Univ. Medical Ctr. (United States); Daniel A. Weiser, Bruce R Pawel, The Children's Hospital of Philadelphia (United States); Metin N. Gurcan, The Ohio State Univ. Wexner Medical Ctr. (United States)

Neuroblastoma is a childhood cancer that starts in very early forms of nerve cells found in an embryo or fetus. It is a highly lethal cancer of sympathetic nervous system that commonly affects children of age five or younger. It accounts for a disproportionate number of childhood cancer deaths and remains a difficult cancer to eradicate despite intensive treatment that includes chemotherapy, surgery, hematopoietic stem cell transplantation, radiation therapy and immunotherapy. A poorly characterized group of patients are the 15% with primary refractory neuroblastoma (PRN) which is uniformly lethal due to de novo chemotherapy resistance. The lack of response to therapy is currently assessed after multiple months of cytotoxic therapy, driving the critical need to develop pre-treatment clinic-biological biomarkers that can guide precise and effective therapeutic strategies. Therefore, our guiding hypothesis is that PRN has distinct biological features present at diagnosis that can be identified for prediction modeling. During visual analysis of PRN slides, stained with hematoxylin and eosin, we observed that patients who survived for less than three years contained large eosin-stained structures as compared to those who survived for greater than three years. So, our hypothesis is that the size of eosin stained structures can be used as a differentiating feature to characterize recurrence in neuroblastoma. To test this hypothesis, we developed an image analysis method that performs stain separation, followed by the detection of large structures stained with Eosin. On a set of 21 PRN slides, stained with hematoxylin and eosin, our image analysis method predicted the outcome with 85.7% accuracy.

9420-8, Session 2

Confocal fluorescence microscopy for detection of cervical preneoplastic lesions

Fahime Sheikhzadeh, The BC Cancer Agency Research Ctr. (Canada) and The Univ. of British Columbia (Canada); Rabab K. Ward, The Univ. of British Columbia (Canada); Anita Carraro, The BC Cancer Agency Research Ctr. (Canada); Zhaoyang Chen, The British Columber Cancer Research Ctr. (Canada); Dirk van Niekerk, British Columbia Cancer Agency (Canada); Calum E. MacAulay, The BC Cancer Agency Research Ctr. (Canada) and The Univ. of British Columbia (Canada); Michele Follen, Texas Tech Univ. Health Sciences Ctr. (United States); Pierre M. Lane, The BC Cancer Agency Research Ctr. (Canada) and The Univ. of British Columbia (Canada); Martial Guillaud, The BC Cancer Agency Research Ctr. (Canada)

We examined and established the potential of ex-vivo fluorescence confocal microscopy for differentiating between normal cervical tissue, low grade intraepithelial lesions (LGSILs), and high grade intraepithelial lesions

(HGSILs). Our objectives were to i) quantify features that describe nuclear and cellular morphology and tissue architecture in confocal microscopic images of fresh cervical biopsies and ii) determine the accuracy of HGSIL detection via confocal microscopy. Cervical biopsy specimens of colposcopically normal and abnormal tissues obtained from 15 patients were evaluated by fluorescence confocal microscopy. Confocal images were analyzed and ~200 morphological and architectural features were calculated at the nuclear, cellular, and tissue level. For the purpose of this study, we used four features to delineate disease grade including nuclear size, cell density, estimated nuclear-cytoplasmic (ENC) ratio, and the average of three nearest Delaunay neighbours distance (3NDND). In each case, these features were correlated to histopathological diagnosis by a board-certified gynaecologic pathologist. Our preliminary results showed that disease grade defined based on ENC ratio and 3NDND correlated well with histopathological diagnoses. The Spearman correlation coefficient between each of these two features and the histopathological diagnosis was higher than the correlation coefficient between colposcopic appearance and histopathological diagnosis. Both the sensitivity and specificity of ENC ratio for detecting HGSILs were 100%. Quantitative tissue phenotype analysis of fluorescence confocal images shows the potential to discriminate HGSILs from LGSILs and normal tissues. This approach could be used to help clinicians identify HGSILs in a clinical setting.

9420-9, Session 2

Computer assisted detection and analysis of tall cell variant papillary thyroid carcinoma in histological images

Edward Kim, Villanova Univ. (United States); Zubair Wahid Baloch, Caroline S. Kim, Univ. of Pennsylvania Health System (United States)

The number of new cases of thyroid cancer are dramatically increasing as incidences of this cancer have more than doubled since the early 1970s. Tall cell variant papillary thyroid carcinoma is one type of thyroid cancer that is more aggressive and has a poorer prognosis. This variant can be identified through visual characteristics of cells in histological images. Thus, we created a fully automatic algorithm that is able to segment cells using a multi-stage approach. Our method learns the statistical characteristics of a cell during the segmentation process and utilizes this prior information for a more accurate result. We are able to analyze the detected regions and report cell data that could be used to assist in clinical diagnosis.

9420-10, Session 3

Automated detection of prostate cancer in digitized whole-slide images of H and E-stained biopsy specimens

Geert Litjens, Babak Ehteshami Bejnordi, Nadya Timofeeva, Ghedhban Swadi, Radboud Univ. Nijmegen Medical Ctr. (Netherlands); Iringo Kovacs, Deventer Hospital (Netherlands); Christina A. Hulsbergen-van de Kaa, Jeroen van der Laak, Radboud Univ. Nijmegen Medical Ctr. (Netherlands)

Automated detection of prostate cancer in digitized H&E whole-slide images is an important first step for computer-driven grading. Most automated grading algorithms work on preselected image patches as they are too computationally expensive to calculate on the multi-gigapixel whole-slide images. An automated multi-resolution cancer detection system could reduce the computational workload for subsequent grading and quantification in two ways: by excluding areas of definitely normal tissue within a single specimen or by excluding entire specimens which do not contain any cancer. In this work we present a multi-resolution cancer detection algorithm geared towards the latter. The algorithm methodology is as follows: at a coarse resolution the system uses superpixels, color histograms and local binary patterns in combination with a random forest classifier to assess the likelihood of cancer. The five most suspicious superpixels are identified and at a higher resolution more computationally expensive graph and gland features are added to refine classification for these superpixels. Our methods were evaluated in a data set of 204 digitized whole-slide H&E stained images of MR-guided biopsy specimens from 163 patients. A pathologist exhaustively annotated the specimens for areas containing cancer. The performance of our system was evaluated using ten-fold cross-validation, stratified according to patient. Image-based receiver-operating characteristic (ROC) analysis was subsequently performed where a specimen containing cancer was considered positive and specimens without cancer negative. We obtained an area under the ROC curve of 0.96 and a 0.4 specificity at a 1.0 sensitivity.

9420-11, Session 3

Correlating gland orientation patterns on ex vivo 7 Tesla MRI with corresponding histology for prostate cancer diagnosis: preliminary analysis

Asha Singanamalli, Case Western Reserve Univ. (United States); Sailaja Pisipati, Adnan Ali, Victoria Wang, Cheuk Ying Tang, Bachir Taouli, Ashutosh K. Tewari, Icahn School of Medicine at Mount Sinai (United States); Anant Madabhushi, Case Western Reserve Univ. (United States)

Advances in 7 Tesla (T) magnetic resonance imaging (MRI) have begun to pave the way for next generation high resolution radiological imaging. Recent work has explored the ability of 7T MRI to image prostate with the goal of achieving improved accuracy in prostate cancer (CaP) diagnosis. As CaP ground truth can only be determined on pathology, the value of 7T MRI in CaP diagnosis can only be validated by assessing its correlation with pathology. Previous work has shown that patterns of glandular orientation, as captured quantitatively by co-occurring gland tensors (CGTs), are able to distinguish between tumor and benign tissues with near perfect accuracy on pathology. Given that 7T ex vivo prostate magnetic resonance imaging (MRI) enables visualization of glands, we assess the feasibility computing CGTs to diagnose prostate cancer (CaP) on radiology. 7T MRI was acquired from two excised prostate specimen, following which they were sectioned, stained, digitized and annotated for CaP and benign regions. These annotations were mapped from histology onto MRI via landmark based thin plate spline registration. Region growing algorithm was used to automatically segment visible glands on both MRI and histology, using which 13 CGT features were computed and compared across the two modalities. Preliminary findings indicate that differences in CGT feature values between benign and tumor regions are preserved across the two modalities, which suggests that 7T MRI may sufficiently capture disorder in gland orientations to provide highly accurate CaP diagnosis.

9420-12, Session 3

Inter-observer variability in the classification of ovarian cancer cell type using microscopy: a pilot study

Marios A. Gavrielides, U.S. Food and Drug Administration (United States); Brigitte M. Ronnett, Russell Vang, The Johns Hopkins Hospital (United States); Jeffrey D. Seidman, U.S. Food and Drug Administration (United States)

It has been determined that different cell types of ovarian carcinoma have different molecular profiles, exhibit different behavior, and might benefit from type-specific treatment. They also display different histopathology

features, and different criteria are used for each cell type classification. Inter-observer variability for the task of classifying ovarian cancer cell types is an under-examined area of research. This study served as a pilot study to quantify observer variability related to the classification of ovarian cancer cell types and to extract valuable data for designing a validation study. Three observers with expertise in gynecologic pathology reviewed 114 cases of ovarian cancer with optical microscopy, with specific guidelines for classifications into distinct cell types. For 93 cases all 3 pathologists agreed on the same cell type, for 18 cases 2 out of 3 agreed, and for 3 cases there was no agreement. Across cell types with a minimum sample size of 10 cases, agreement between all three observers was {91.1%, 80.0%, 90.0%, 78.6%, 100.0%, 61.5%} for the high grade serous carcinoma, low grade serous carcinoma, endometrioid, mucinous, clear cell, and carcinosarcoma cell types respectively. The wide range of concordance suggests that each cell type should be adequately sampled in validation studies. These results will be used in an ongoing study to compare optical and digital pathology (DP) for this task and identify any limitations of DP for specific cell types. In addition, results will help define a possible role of computer-aided diagnosis to improve the efficacy of pathologists for this task.

9420-13, Session 3

Integration of co-localized glandular morphometry and protein biomarker expression in immunofluorescent images for prostate cancer prognosis

Richard Scott, Faisal Khan, Jack Zeineh, Michael Donovan, Gerardo Fernandez, Icahn School of Medicine at Mount Sinai (United States)

Immunofluorescence (IF) image analysis of tissue pathology has proven to be extremely valuable and robust in developing prognostic assessments of disease, particularly in prostate cancer. There have been significant advances in the literature in quantitative biomarker expression as well as characterization of glandular architectures in discrete gland rings. However, while biomarker and glandular morphometric features have been combined as separate predictors in multivariate models, there is a lack of integrative features for biomarkers co-localized within specific morphological sub-types; for example the evaluation of androgen receptor (AR) expression within Gleason 3 glands only. In this work we propose a novel framework employing multiple techniques to generate integrated metrics of morphology and biomarker expression. We demonstrate the utility of the approaches in predicting clinical disease progression in images from 326 prostate biopsies and 373 prostatectomies. Our proposed integrative approaches yield significant improvements over existing IF image feature metrics. This work presents some of the first algorithms for generating innovative characteristics in tissue diagnostics that integrate co-localized morphometry and protein biomarker expression.

9420-14, Session 3

Toward automatic Segmentation and Quantification of Tumor and Stroma Tissue in Whole-Slide Images of H and E stained Rectum Carcinomas

Oscar G. F. Geessink, Lab. of Pathology East Netherlands (Netherlands) and Medisch Spectrum Twente (Netherlands) and Univ. Twente (Netherlands); Alexi Baidoshvili, Gerard Freling, Lab. of Pathology East Netherlands (Netherlands); Joost M. Klaase, Medisch Spectrum Twente (Netherlands); Cornelis H. Slump, Ferdinand van der Heijden, Univ. Twente (Netherlands)

Visual estimation of tumor and stroma proportions in microscopy images

yields a strong, Tumor-(lymph)Node-Metastasis (TNM) classification-independent, predictor for patient survival in colorectal carcinomas. Therefore, it is also a potent (contra)indicator for adjuvant chemotherapy. However, tissue quantification through visual estimation is highly subject to intra- and interobserver variability. The aim of this study is to develop and clinically validate an automated method for reliable segmentation and quantification of tumor and stroma tissue in hematoxylin & eosin (H&E) stained microscopy slides of rectum carcinomas.

A tissue segmentation algorithm, based on supervised machine learning and pixel classification, was developed and validated using tissue slides that were prepared from surgically excised rectum carcinomas in patients who had not received neoadjuvant chemoradiotherapy. Whole-slide scanning was performed at 20? magnification (~0.21μm2/pixel). A total of 40 images (4 million pixels each) were extracted from 20 whole-slide images at sites showing various tumor-stroma ratios. Experienced pathologists provided detailed annotations. The performance of the algorithm was evaluated using cross-validation.

The classification error of the algorithm was 9.4% (SD = 3.2%). Compared to visual estimation by pathologists, the algorithm proved to be 7.3 times (P = 0.033) more accurate in quantifying tissues, also showing 60% less variability.

Automatic tissue quantification proved to be superior. Our next goal is to apply this method to a large patient database to further investigate the relationship between tissue proportions and clinical outcome in order to validate this quantitative method, expecting to contribute to better personalized medicine.

9420-15, Session 4

Automatic glandular and tubule detection in histological grading of breast cancer

Kien T. Nguyen, Chukka Srinivas, Micheal Barnes, Christophe Chefd'hotel, Ventana Medical Systems, Inc. (United States)

In the popular Nottingham histologic score system for breast cancer grading, the pathologist analyzes the H&E tissue slides and assigns a score, in the range of 1-3, for tubule formation, nuclear pleomorphism and mitotic activity in the tumor regions. The scores from these three factors are added to give a final score, ranging from 3-9 to grade the cancer. Tubule score, which reflects tubular formation, is a value in 1-3 given by manually estimating the percentage of glandular regions in the tumor that form tubules. In this paper, given an H&E tissue image representing a tumor region, we propose an automated algorithm to detect glandular regions and detect the presence of tubules in these regions. This algorithm (i) detects all nuclei and lumen candidates in the input image, (ii) identify tumor nuclei from the detected nuclei and identify true lumina from the lumen candidates using a random forest classifier, and (iii) forms the glandular regions by grouping the closely located tumor nuclei and lumina using a graph-cut-based method. The glandular regions containing true lumina are considered as the ones that form tubules (tubule regions). To evaluate the proposed method, we calculate the tubule percentage (TP), i.e., the ratio of the tubule area to the total glandular area for 353 H&E images of the three tubule scores, and plot the distribution of these TP values. This plot shows the clear separation among these three scores, suggesting that the proposed algorithm is useful in distinguishing images of these tubule scores.

9420-16, Session 4

A multi-scale superpixel classification approach for region of interest detection in whole slide histopathology images

Babak Ehteshami Bejnordi, Geert Litjens, Meyke Hermsen, Nico Karssemeijer, Jeroen van der Laak, Radboud Univ. Nijmegen Medical Ctr. (Netherlands)

This paper presents a new algorithm for the detection of regions of interest in whole slide histopathology images. The proposed algorithm generates and classifies superpixels at multiple resolutions to detect regions of interest. The algorithm emulates the way the pathologist examines the whole slide histopathology image by processing the slide at low magnifications and performing more sophisticated analysis only on areas requiring more detailed information. However, instead of the traditional usage of fixed sized rectangular patches for the identification of relevant areas, we use superpixels as the visual primitives to detect regions of interest. Rectangular patches can span multiple distinct structures, thus degrade the classification performance. The proposed multi-scale superpixel classification approach yields strong performance for the identification of the regions of interest. For the evaluation, a set of 10 whole slide histopathology images of breast tissue were used. Empirical evaluation of the performance of our proposed algorithm relative to expert manual annotations shows that the algorithm achieves an area under the Receiver operating characteristic (ROC) curve of 95.83%, demonstrating the efficacy of the proposed algorithm for the detection of regions of interest.

9420-17, Session 4

High-definition Fourier transform infrared spectroscopic imaging of breast tissue

L. Suzanne Leslie, Beckman Institute, Univ. of Illinois at Urbana-Champaign (United States); Andre Kadjacsy-Balla, Univ. of Illinois at Chicago (United States) and Univ. of Illinois Cancer Ctr. (United States); Rohit Bhargava, Univ. of Illinois at Urbana-Champaign (United States) and Univ. of Illinois Cancer Ctr. (United States)

Histopathology forms the gold standard for cancer diagnosis and therapy, and generally relies on structural morphology of tissue. Fourier-transform infrared (FT-IR) imaging is a vibrational spectroscopic imaging technique that provides the spatial specificity of microscopy at magnifications used in pathology. Infrared absorption by the tissue creates a strong signal where the spectrum at each pixel is a quantitative "fingerprint" of the composition of the sample. It is therefore essential to have the highest possible spatial resolution and signal-to-noise (SNR) ratio for a given application. In this paper, we discuss how to optimize common optical parameters such as the numerical aperture (NA) and magnification of the microscope optics in order to achieve minimal pixel size and maximal spatial resolution in high-definition (HD) FTIR images, and demonstrate these relationships using FT-IR images of breast tissue.

Typically, in order to maximize SNR, commercial FT-IR instruments have an image pixel size of approximately 6 μm x 6 μm. This lack of spatial resolution can make it difficult or impossible to distinguish certain cell types in breast tissue, limiting its usefulness for histopathology. The minimum achievable pixel size with an acceptable SNR is affected by many parameters in the FT-IR configuration, beginning with the intensity of the IR source and the physical size of the pixels in the detector itself. By increasing the NA of the microscope objective and total magnification of the microscope, the pixel size can be decreased to approximately 1 μm and spatial resolution can be greatly improved.

9420-18, Session 4

Multi-class stain separation using independent component analysis

Nicholas A. Trahearn, Nasir M. Rajpoot, The Univ. of Warwick (United Kingdom); David Snead, Univ. Hospitals Coventry and Warwickshire NHS Trust (United Kingdom); Ian A. Cree, Warwick Medical School (United Kingdom)

Stain separation is the process whereby a full colour histology section image is transformed into a series of single channel images, each corresponding to a given stain's expression. Many algorithms in the field of digital pathology are concerned with the expression of a single stain, thus stain separation is a key preprocessing step in these situations.

We present a new versatile method of stain separation. The method uses Independent Component Analysis (ICA) to determine a set of statistically independent vectors, corresponding to the individual stain expressions. In comparison to other popular approaches, such as PCA and NNMF, we found that ICA gives a superior projection of the data with respect to each stain. In addition, we introduce a correction step to improve the initial results provided by the ICA coefficients.

Many existing approaches only consider separation of two stains, with primary emphasis on Haemotoxylin and Eosin. We show that our method is capable of making a good separation when there are more than two stains present. We also demonstrate our method's ability to achieve good separation on a variety of different stain types.

9420-19, Session 4

Minimum slice spacing required to reconstruct 3D shape for serial sections of breast tissue for comparison with medical imaging

Sara Reis, Bjoern Eiben, Thomy Mertzanidou, John Hipwell, Univ. College London (United Kingdom); Meyke Hermsen, Jeroen van der Laak, Radboud Univ. Nijmegen Medical Ctr. (Netherlands); Sarah Pinder, King's College London (United Kingdom); Peter Bult, Radboud Univ. Nijmegen Medical Ctr. (Netherlands); David Hawkes, Univ. College London (United Kingdom)

Radiological imaging is used routinely for tumour detection, characterisation and staging, however histopathology is considered the gold standard for breast cancer diagnosis, specifically to confirm malignancy, tumour size and type, distribution and extent of the disease. The precise relationship between the signal intensities in radiological imaging and the underlying tissue microstructure is not completely understood. Establishing spatial correspondence between histopathological and radiological images could improve our understanding of this relationship with respect to both the tumour and its microenvironment and determine patient prognosis. Moreover, relating information at different resolution scales is challenging due to the obscuration of corresponding features.

Reconstructing 3D volumes from histology images could be the key to interpreting and relating the radiological image signal to tissue microstructure. Moreover, the maximum spacing between histological sections through a fixed surgical specimen required to create a 3D reconstruction to a specific tolerance, without the loss of 3D information needed for alignment and to determine relevant 3D information for image signal interpretation, is unclear. The goal of this study is to determine the minimum sampling required to create a 3D reconstruction of the specimen to a specific tolerance. To this end, we evaluate the 3D surface reconstruction of a mammary duct with different spacing between each histology slice while decreasing the number of slices used. We present initial results for one mastectomy case where 33 consecutive histology slides were acquired.

9420-20, Session 4

Color model comparative analysis for breast cancer diagnosis using H and E stained images

Xingyu Li, Konstantinos N. Plataniotis, Univ. of Toronto (Canada)

Digital cancer diagnosis is a research realm where signal processing

techniques are used to analyze and to classify color histopathology images. Different from grayscale image analysis of X-ray imaging or magnetic resonance imaging, color in histopathology images conveys a large amount of histological information and thus plays a significant role in cancer diagnosis. Though color information is frequently used in existing histopathology works, as today, there is few study on color model selections for feature extraction in cancer diagnosis.

This paper addresses the problem of color space selection for digital cancer classification using H&E stained images, and investigates the effectiveness of various color models (RGB, HSV, CIE L*a*b*, and stain-dependent H&E decomposition model) in breast cancer diagnosis. Particularly, we build a diagnosis framework as a comparison benchmark and take specific concerns of medical decision systems into account in evaluation. The evaluation methodologies include feature discriminate power evaluation and final diagnosis performance comparison. Experimentation on a publicly accessible histopathology image set suggests that the H&E decomposition model outperforms other assessed color spaces. For reasons behind various performance of color spaces, our analysis via mutual information estimation demonstrates that color components in the H&E model are less dependent, and thus most feature discriminate power is collected in one channel instead of spreading out among channels in other color spaces.

9420-21, Session PSWed

Performance assessment of automated tissue characterization for prostate H and E histopathology

Matthew D. DiFranco, Medizinische Univ. Wien (Austria); Hayley M. Reynolds, Peter MacCallum Cancer Ctr. (Australia) and The Univ. of Melbourne (Australia); Catherine Mitchell, Scott Williams, Prue Allan, Peter MacCallum Cancer Ctr. (Australia); Annette Haworth, Peter MacCallum Cancer Ctr. (Australia) and The Univ. of Melbourne (Australia)

Reliable automated prostate tumor detection and characterization in whole mount histology images is sought in many applications, including post-resection tumor staging and for multiple research applications including providing ground-truth data for multi-parametric MRI interpretation. In this study, an ensemble-based supervised classification algorithm was trained on textural image features and tested using a lower resolution, independent data set to assess feature invariance across magnifications and data sources. An ensemble of 20 classifiers were trained using multiple 2-fold splits of 15 annotated, digital quarter-mount H&E slides obtained at 400x total magnification. Tumor probability estimates were generated on a validation set of 8 digital whole-mount images obtained at 200x magnification from 8 patients at a different medical center. ROC analysis based on the per-tile ensemble probability estimates within expert pathologist (EP) annotated regions show area under the curve (AUC) approaching 0.92 for individual images. However, visual inspection of heat maps indicates variable specificity, particularly due to benign patterns such as benign prostatic hyperplasia (BPH). Preliminary investigations have demonstrated that specificity of the model may be improved by including additional pattern-specific image-based features such as cell density, lumen estimates, and morphological parameters within the machine learning framework. More detailed EP annotations will also improve the reliability of validation, and enable more accurate tissue characterization.

9420-22, Session PSWed

Nucleus detection using gradient orientation information and linear least squares regression

Jin Tae Kwak, National Institutes of Health (United States); Stephen M. Hewitt, National Cancer Institute (United

States); Sheng Xu, National Institutes of Health (United States); Peter A. Pinto, National Cancer Institute (United States); Bradford J. Wood, National Institutes of Health (United States)

Computerized histopathology image analysis enables an objective, efficient, and quantitative assessment of digitized histopathology images. Such analysis often requires an accurate and efficient detection and segmentation of histological structures such as cells and nuclei. The segmentation is used to characterize tissue specimens and to determine the disease status or outcomes. The segmentation of nuclei, in particular, is challenging due to the overlapping or clumped nuclei. Here, we proposed a nucleus seed detection method for the individual and clumped nuclei that utilizes the gradient orientation or direction information. The initial nuclear segmentation was provided by a multiview boosting approach. The angle of the gradient orientation was computed and traced for the nuclear boundaries. Taking the first derivative of the angle of the gradient orientation, high concavity points (junctions) were discovered. False junctions were found and removed by adopting a greedy search scheme with the goodness-of-fit statistic in a linear least squares sense. Using the final set of the junctions, we generated the list of seeds in tissue images. The method achieved an overall precision of 0.89 and a recall of 0.88 in comparison to the manual segmentation.

9420-23, Session PSWed

Toward consistent cell segmentation: quality assessment of cell segments via appearance and geometry features

Andrew Brinker, Annika Fredrikson, The Univ. of North Carolina at Charlotte (United States); Xiaofan Zhang, Richard Sourvenir, UNC Charlotte (United States); Shaoting Zhang, The Univ. of North Carolina at Charlotte (United States)

Automatic histopathological image analysis for use in computer-aided diagnosis (CAD) relies upon accurate cell segmentation to inform later processing of cell-level information. Cell segmentation of histopathological images is complicated by wide image variety, including variation in inter-cell density and intra-cell intensity. Most existing methods struggle to consistently segment this wide variety of images. In this paper we propose a method to consistently identify low-quality segmentation results of cells in the first step toward segmentation correction. This process can be applied as a "plugin" to easily improve results from a variety of methods while being independent of each method's individual processes. With minimal supervised training and a proposed feature set of five easily calculable metrics our method can differentiate high and low-quality segmentation results with above 80% accuracy. The method is also easily adaptable to changes in segmentation process, segment features, and image modality, making it particularly interesting as an option for overcoming the difficulties of individual segmentation methods.

9420-24, Session PSWed

Adaptive whole slide tissue segmentation to handle inter-slide tissue variability

Kien T. Nguyen, Ting Chen, Joerg Bredno, Chukka Srinivas, Christophe Chefd'hotel, Ventana Medical Systems, Inc. (United States); Solange Romagnoli, Astrid Heller, Oliver Grimm, Fabien Gaire, Roche Diagnostics GmbH (Germany)

Automatic whole slide (WS) tissue image segmentation is an important problem in digital pathology. A conventional classification-based method (referred to as CCb method) to tackle this problem is to train a classifier on a pre-built training database (pre-built DB) obtained from a set of training WS images, and use it to classify all image pixels or image patches (test

samples) in the test WS image into different tissue types. This method suffers from a major challenge in WS image analysis: the strong inter-slide tissue variability (ISTV) (the variability of tissue appearance from slide to slide). To address the ISTV, we propose a slide-adapted classification (SAC) method, to extend the CCb method. We assume that besides regions with high variation, there are regions with lower variation from the pre-built DB. Hence, the SAC method performs a two-stage classification: first classifies all test samples in a WS image and compute their classification confidence scores. Next, the samples classified with high confidence scores (samples being reliably classified due to their low variation from the pre-built DB) are combined with the pre-built DB to generate an adaptive training DB to reclassify the low confidence samples. The method is motivated by the large number of high confidence samples obtained (large image size) and the lower variability between the low and high confidence samples (both belonging to the same image) compared to the ISTV. Using the proposed SAC method to segment a large dataset of 24 WS images, we improve the accuracy over the CCb method.

9420-25, Session PSWed

A novel spectral imaging system for use during pancreatic cancer surgery

Joseph A. Peller, Susan R. Trammell, Mehrdad Abolbashari, Faramarz Farahi, The Univ. of North Carolina at Charlotte (United States)

Pancreatic cancer is the fourth leading cause of cancer death in the United States. Most pancreatic cancer patients will die within the first year of diagnosis, and just 6% will survive five years. Currently, surgery is the only treatment that offers a chance of cure for pancreatic cancer patients. Unfortunately, accurately identifying the margins of tumors in real-time is a significant difficulty during pancreatic cancer surgery and contributes to the low 5-year survival rate. We are developing a hyper-spectral imaging system for real-time tumor margin detection during pancreatic cancer surgery.

Recent research has shown that optical spectroscopy can be used to differentiate between healthy and diseased pancreatic tissue. Specifically, the strengths of the autofluorescence emission from cellular NAD(P)H near 460 nm and extracellular matrix collagen near 400 nm differ in strength and the reflectance spectra differ significantly around 500 nm. We are developing a single-pixel hyperspectral imaging system based on compressive sensing that can detect these spectral differences. Our system provides the spectrum in each pixel of the image; that is spatially resolved spectral information across the entire image area. This system is capable of imaging a large region (2 cm x 2 cm) of tissue with an approximate spatial resolution of 4 mm and spectral resolution of 3 nm in a single image. In this study, we present hyper-spectral imaging of ex vivo porcine pancreatic tissue that demonstrates the ability of our system to differentiate between health and unhealthy tissue.

9420-26, Session PSWed

Detection of high-grade atypia nuclei in breast cancer imaging

Henri Noel, IPAL CNRS (Singapore) and UPMC (Singapore); Ludovic Roux, IPAL, CNRS (Singapore) and Univ. Joseph Fourier (France); Shijian Lu, IPAL, CNRS (Singapore) and Institute for Infocomm Research (Singapore); Thomas Boudier, IPAL, CNRS (Singapore) and UPMC (Singapore) and Bioinformatics Institute (Singapore)

Along with mitotic count, nuclear pleomorphism or nuclear atypia is an important criterion for the grading of breast cancer in histopathology.

Though some works have been done in mitosis detection (ICPR 2012, MICCAI 2013 and ICPR 2014), not much work has been dedicated to

automated nuclear atypia grading, especially the most difficult task of detection of grade 3 nuclei.

We propose the use of Convolutional Neural Networks for the automated detection of cell nuclei, using images from the three grades of breast cancer for training. The images were obtained from ICPR contests. Additional manual annotation was performed to classify pixels into five classes: stroma, nuclei, lymphocytes, mitosis and fat. At total of 3,000 thumbnail images of 101 $\times$ 101 pixels were used for training. By dividing this training set in a 80/20 ratio we could obtain good training results (around 90%).

We tested our CNN on images of the three grades which were not in the training set. High grades nuclei were correctly classified. We then thresholded the classification map and performed basic analysis to keep only rounded objects. Our results show that mostly all atypical nuclei were correctly detected.

We tested our CNN on images of the three grades which were not in the training set. For grade 1 nuclei were mainly classified as lymphocytes, while for grades 2 and 3, nuclei were correctly classified. We then thresholded the classification map and performed basic analysis to keep only rounded objects. Our results show that mostly all atypical nuclei were correctly detected.

9420-27, Session PSWed

A novel texture descriptor for detection of glandular structures in colon histology images

Korsuk Sirinukunwattana, The Univ. of Warwick (United Kingdom); David Snead, Univ. Hospitals Coventry and Warwickshire NHS Trust (United Kingdom); Nasir M. Rajpoot, Qatar Univ. (Qatar) and The Univ. of Warwick (United Kingdom)

The first step prior to any analyses on most histopathological images is the detection of areas of interest. In this work, we present a superpixel-based approach for glandular structure detection in colon histology images. An image is first segmented into superpixels with the constraint on the presence of glandular boundaries. Texture and colour information is then extracted from each superpixel to calculate the probability of that pixel belonging to glandular regions. We also present a novel texture descriptor derived from a region covariance matrix of scattering coefficients. Our approach shows encouraging results for initial detection of glandular structures in colon tissue samples.

9420-28, Session PSWed

A circumscribing active contour model for delineation of nuclei and membranes of megakaryocytes in bone marrow trephine biopsy images

Tzu-Hsi Song, Victor Sanchez, The Univ. of Warwick (United Kingdom); Hesham Eldaly, Haematology Oncology Diagnostic Service, Addenbrooke's Hospital (United Kingdom); Nasir M. Rajpoot, The Univ. of Warwick (United Kingdom) and Qatar Univ. (Qatar)

The assessment of megakaryocytes (MKs) in bone marrow trephine images is an important step in the classification of different subtypes of myeloproliferative neoplasms (MPNs). In general, bone marrow trephine images include several types of cells mixed together, which make it quite difficult to visually identify MKs. In order to aid hematopathologists in the identification and study of MKs, we have developed a framework to efficiently delineate the nuclei and membranes of these cells in digitized bone marrow trephine images using a circumscribing active contour model.

We first employs supervised machine learning approaches to first identify potential MKs and then accurately delineate the corresponding nucleus and membrane using the novel model. Specifically, a number of color and texture features are used in a Naïve Bayesian classifier and an Adaboost classifier to first locate regions with a high probability of depicting MKs. A region-based active contour is then used on the candidate MKs to accurately delineate the boundaries of nucleus and membrane. The proposed active contour employs external forces not only based on pixel intensities, but also on the probabilities of depicting MKs as computed by the classifiers.

Experimental results suggest that the machine learning approach can detect potential MKs with an accuracy of more than 75%. When our region-based active contour is employed on the candidate MKs, the nucleus and membrane boundaries are segmented with an accuracy of more than 80% as measured by the Dice similarity coefficient. Compared to traditional region-based active contours, the use of additional external forces based on the probability of depicting MKs improves segmentation performance and computational time by an average 5%.

9420-29, Session PSWed

Success of digitizing the Dept. of Pathology: Is it just to change the technical platform and go with the slide-scanners or do we need a paradigm when it comes to informatics and workflow?

Mikael Wintell, Sahlgrenska Univ. Hospital (Sweden); Lars Lindsköld, Bo Samulesson, Elisabeth Wehlander, Västra Götaland (Sweden)

Challenges within pathology workflow is that we mix analogue workflow and information with digital coming from slide-scanners and LIS/LIMS.

There is a belief that by just going digital, scanning the slides you will create a great value, but this is just partially true.

By introducing slide-scanners to your department, it will just increase cost and workload, still have exact the same workflow as before, adding procedures concerning scanning the slides.

Can you as a manager justify those cost standing in front of the C-suite? No you can´t!

Our project shows the need to go beyond exchanging technical platform and outside the pathology department to find the big values that justify investments going digital.

Also there is a need for an understandning of information-models as well as healthcare standards to be able to seemless incooperate the referring clinicians workflow into the pathology process. By doing this we will be able to meet the values and requirements of the stakeholders.

Since 2011 , Pathology in Västra Götaland has been preparing to enter the "world" of digital pathology, not just by implementing slide-scanners but also implementation of an unified negotiated information-model, covering the referral to the report.

Summary

Involving the referring clinicians, changing the healthcare subprocess, cancerdetection (pathology), we can justify the investment and create values for the patient and also for the society.

Also we now have the core, creating the virtuell pathology network where we can exchange and accelarate knowledge within the Pathology domain, all in favour for the patients.

9420-30, Session PSWed

Uncertainty in the assessment of immunohistochemical staining with optical and digital microscopy: lessons from a reader study

Marios A. Gavrielides, Brandon Gallas, U.S. Food and Drug Administration (United States); Stephen M. Hewitt, National Cancer Institute (United States)

We recently completed a reader study to compare optical and digital pathology (DP) for the assessment of two tissue-based biomarkers with immunohistochemistry. Eight pathologists reviewed 50 breast cancer whole slides (25 stained with HER2 and 25 with Ki-67) and 2 TMAs (1 stained with HER2, 1 with Ki-67, 97 cores each), using digital and optical microscopy. All reviews took place in a single office, using the same microscope, same computer/color calibrated monitor combination, and the same ambient light, in order to eliminate sources of variability due to these parameters. Agreement analysis was performed using the Kendall's tau-b metric and percent correct agreement. Here, we discuss the lessons learned from our reader study, focusing on sample size issues in validation studies of digital pathology and related guidelines that were published recently. Results showed relatively high overall inter-observer and inter-modality agreement. However, significant uncertainty was observed for the whole slide evaluation with 95% confidence intervals (CI) in the order of 0.30 for the Kendall's tau-b metric, despite taking care to reduce sources of uncertainty. For the better-sampled TMAs, CIs were in the order of 0.15. It can be deduced that the sample size of 25 slides for each biomarker was not adequate even though it is in line with recent guidelines for the validation of DP from the College of American Pathologists (20 slides for immunohistochemistry without specifying task). As such, attention to sample size needs to be taken, especially when pooling cases of different tasks and subgroup analyses are planned.

9420-31, Session PSWed

Improved segmentation of abnormal cervical nuclei using a graph-search based approach

Ling Zhang, The Univ. of Iowa (United States); Shaoxiong Liu M.D., Peoples Hospital of Nanshan District (China); Tianfu Wang, Siping Chen, Shenzhen University (China); Milan Sonka, The Univ. of Iowa (United States)

Reliable segmentation of abnormal nuclei in cervical cytology is of paramount importance in automation-assisted screening techniques. This paper presents an accurate and efficient novel method for segmenting abnormal nuclei using a graph-based approach. More specifically, the proposed method is built on our previous nucleus segmentation framework, and focuses on the refinement of coarse segmentation. The refinement relies on a transform that maps round-like border in the Cartesian coordinate system into lines in the polar coordinate system. The costs consisting of nucleus-specific edge and region information are assigned to the nodes. The globally optimal path in the constructed graph is then identified by dynamic programming. Experiments on 64 abnormal nuclei from 15 cervical cytology images showed that our method achieved F-measure of 0.935 and correlation of 0.982 compared with manual segmentation, substantially outperforming our previous method.

9420-32, Session PSWed

An automated approach to improve the efficacy in detecting residual cancer cell for facilitating prognostic assessment of leukemia: An initial study

Yuchen Qiu, The Univ. of Oklahoma (United States); Xianglan Lu, The Univ. of Oklahoma Health Sciences Ctr. (United States); Maxine Tan, The Univ. of Oklahoma (United States); Shibo Li, The Univ. of Oklahoma Health Sciences Ctr. (United States); Hong Liu, Bin Zheng, The Univ. of Oklahoma (United States)

Detecting residual cancer cells is a critical step in evaluating leukemia prognosis and allying optimal patient management plan after initial cancer remission. However, due to the limited number of visually analyzed cells (e.g., 200), the current manual detection method has very low sensitivity and accuracy. In order to improve the efficacy of detecting residual cancer cells, we investigated a new automated approach that combines a whole-slide scanning method and a computer aided detection (CAD) scheme to increase the number of identified cells. To test its feasibility, two clinical specimens obtained from two patients undergoing leukemia treatment were selected and used in this study. Using a commercialized fluorescent microscope, each specimen was scanned and digitized with one layer using an 40? objective lens. After the image acquisition, CAD scheme was applied to detect and segment the regions of interest (ROIs) depicting clinically analyzable cells. On each ROI, CAD scheme recognizes and counts the fluorescent dots by computing size, intensity, and relative distance of the labeled candidate dots inside the cell nucleus. The result shows that this automated approach detected 334 and 405 suspiciously abnormal cells from the 4546 and 3807 clinically analyzable ROIs, which resulted in detecting a significantly more number of abnormal cells than those previously visually detected by the clinicians in the hospital (122 and 160). The study demonstrated the feasibility of using this new technique to help the clinicians achieve high accuracy of leukemia prognostic assessment in the future.

9420-33, Session PSWed

An accurate method of extracting fat droplets in liver images for quantitative evaluation

Masahiro Ishikawa, Naoki Kobayashi, Hideki Komagata, Kazuma Shinoda, Saitama Medical Univ. (Japan); Masahiro Yamaguchi, Tokyo Institute of Technology (Japan); Tokiya Abe, Akinori Hashiguchi, Michiie Sakamoto, Keio Univ. (Japan)

The quantitative evaluation of steatosis in liver pathological tissue images is a promising index of nonalcoholic fatty liver disease (NAFLD) and the risk of hepatocellular carcinoma (HCC). The resulting values are also important for the automatic classification of HCC images to enhance diagnosis accuracy, because the existence of many fat droplets is otherwise likely to create errors in quantifying the morphological features used in the process. This study introduces a method that can automatically detect, and exclude, regions with many fat droplets by using the feature values of color information, the arrangement of cell nuclei, and shape information. We implement the method and confirm that it can accurately detect fat droplets and quantify the fat droplet ratio of actual images. We also investigate the effective characteristics that contribute to its accuracy.

9420-35, Session PSWed

Multi-stained whole slide image alignment in digital pathology

Gloria Bueno, Oscar Deniz, Univ. de Castilla-La Mancha (Spain); David Toomey, Catherine Conway, Leica Biosystems (Ireland)

In Digital Pathology, one of the most simple and yet most useful feature is the ability to view serial sections of tissue simultaneously on a computer monitor. This enables the pathologist to evaluate the histology and expression of multiple markers for a patient in a single review. However, the rate limiting step in this process is the time taken for the pathologist to open each individual image, align the sections within the viewer, with a maximum of four slides at a time, and then manually move around the section. In addition, due to tissue processing and pre-analytical steps, sections with different stains have non-linear variations between the two acquisitions, that is, they will stretch and change shape from section to section.

To date, no solution has come close to a workable solution to automatically align the serial sections into one composite image. This research work address this problem to obtain an automated serial section alignment tool enabling the pathologists to simply scroll through the various sections in a single viewer. To this aim an intensity-based registration method using mutual information as a similarity metric, an optimizer based on an evolutionary process and a bilinear transformation has been used. To characterize the performance of the algorithm 4 different serial sections stained with hematoxiline-eosine (HE), estrogen receptor (ER), progesterone receptor (PR) and human epidermal growth factor receptor 2 (Her2), have been considered. The qualitative results obtained are promising, with average computation time of 26.4s for 1660x799 images running interpreted code.

9420-36, Session PSWed

Automatic choroid cells segmentation and counting based on approximate convexity and concavity of chain code in fluorescence microscopic image

Weihua Lu, Xinjian Chen, Weifang Zhu, Lei Yang, Zhaoyuan Cao, Soochow Univ. (China); Haoyu Chen, Joint Shantou International Eye Center of Shantou University and The Chinese University of Hong Kong (China)

METHOD AND MATERIALS

The proposed method consists of four main steps. First, a pre-processing were applied to reduce the noise. Second, the boundary information was used to generate the Freeman chain codes. Third, the concave points were constructed. Finally, cells segmentation and counting were computed. More details are given below:

(1) Pre-processing

As there are some impurities in the cell images with material, a threshold filter and the morphological transform were applied to reduce the noise. The filtered images were corroded and dilated repeatedly by a 3*3 template and the contour of the cell was extracted.

(2) Contour coding

After the contour of the cell was extracted, the contour was encoded into the Freeman chain code along the clockwise direction[3-4]. Figure 1 showed the method of encoding cell contour.

(3) Concave points construction

As the difference of the chain code can reflect the curvature of the contour, the concave points can be constructed based on the difference of the chain code. The definition of the difference of the chain code was given below:

$R(i)=|C(i)-C(i-1)+8|$ MOD 8 (if $R(i)>3$, then $R(i)=R(i)+8$) (1)

A(i)=A(i-1)+R(i) (2)

Sum(i)=A(i)+A(i-1)+A(i-2) (3)

Diff(i)=Sum(i+3)-Sum(i) (4)

where i was the point on the contour. A(i) was the absolute code, A(0)=0. C(i) represented the Freeman code. R(i) was the relative code. When the difference of the chain code Diff(i) was bigger than the experience value, the concave point could be found on the contour. The experience value here was set to 3.

(4) Correction and segmentation

There are kinds of overlapped cells cases in the cell images, such as two or more cells adhered. Interestingly, the overlapped cells have a characteristic: the contour of the overlapped cells have two concave points at least. After the adjacent concave points were merged into one concave points and the alone concave points were excluded, the contour which have two concave points can be segmented straight. If three or more concave points exist, the characteristics of area and shape of the cells should be considered , which is one of our work in the further research.

RESULTS

The proposed method was tested on 15 images. The original fluorescence microscopy image sizes was 1388*1040 pixels. Supervised by the experienced ophthalmologist, the manually counted cell number is MN. The automatically counted cell number is AN. Fig.2 shows the true positive rate (TPR) and the false positive rate(FPR)of the proposed algorithm. , . Here TP, FP, FN represents true positive, false positive and false negative ,respectively.

9420-37, Session PSWed

Detecting cells in time varying intensity images in confocal microscopy for gene expression studies in living cells

Debasis Mitra, Florida Institute of Technology (United States); Rostyslav Boutchko, Lawrence Berkeley National Lab. (United States); Judhajeet Roy, Marit Nilsen-Hamilton, Iowa State Univ. (United States)

In this work we present a time-lapsed confocal microscopy image analysis technique for an automated gene expression study of multiple single living cells. Fluorescent Resonance Energy Transfer (FRET) is a technology by which molecule-to-molecule interactions are visualized. We analyzed a dynamic series of ~102 images obtained using confocal microscopy of fluorescence in yeast cells containing RNA reporters that give a FRET signal when the gene promoter is activated. For each time frame, separate images are available for three spectral channels and the integrated intensity snapshot of the system. A large number of time-lapsed frames must to be analyzed to identify each cell individually across time and space, as it is moving in and out of the focal plane of the microscope. This makes it a difficult image processing problem. We have proposed an algorithm here, based on scale-space technique, that solves the problem satisfactorily. The algorithm has multiple directions for even further improvement. The ability to rapidly measure changes in gene expression simultaneously in many cells in a population will open the opportunity for real-time studies of the heterogeneity of genetic response in a living cell population and the interactions between cells that occur in a mixed population, such as the ones found in the organs and tissues of multicellular organisms.