SPIE Medical Imaging

Technical Summaries

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Conference Dates: 12-17 February 2011

Disney's Coronado Springs Resort
Lake Buena Vista (Orlando Area), Florida USA

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Contents

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Conference 7961: Physics of Medical Imaging

Sunday-Thursday 13-17 February 2011 • Part of Proceedings of SPIE Vol. 7961
Medical Imaging 2011: Physics of Medical Imaging

7961-01, Session 1

Economics in medical imaging

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Powerful forces are reshaping the health system in ways that affect all stakeholders-patients, providers, payers, legislators and regulators. The fundamental as yet unresolved tension facing the system is how to provide health care to all citizens of the United States in an affordable way that adequately supports the provider base and does not lead to either rationing of care or stifling of innovation and creativity.

The imaging community will be especially challenged because we are in a prolonged phase of break through developments in new technology. These break throughs have been widely embraced by medical practitioners who clearly see the value to their patients. As a consequence, growth in delivery of imaging services has far outstripped the average growth of health services. Imaging has been singled out for reimbursement cuts to mitigate the cost impact of rapid growth on the health system.

Cutbacks in Medicare payments associated with the Deficit Reduction Act of 2005 (DRA) made delivery of outpatient services far less attractive and led to a sharp drop in demand for imaging equipment. This negative impact has been further perpetuated by the recession and uncertainty surrounding health care reform.

Apart from the immediate negative impact on the vendor community, prolonged reductions in demand could negatively influence corporate research and development spending with a reduction in the rate of development of new imaging technologies. Optimistically, the dynamics in the United States will be offset by more rapid growth in other parts of the world, most importantly, China.

7961-02, Session 1

Lateral organic photodetectors for imaging applications

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Organic semiconductor detectors have always been in active research interest of researchers due to its low fabrication cost. Vertical organic detectors have been studied a lot in the past but not much of the works have been done on lateral organic detectors. The lateral design has an advantage over the vertical design that it is easy to fabricate and can be easily integrated with the backplane TFT imager circuit. Integrating an organic photodetectors with TFT imager can improve the over all sensitivity of the imager. How ever the lateral design limits the fillfactor.

Here in our work we propose a new bilayered lateral organic photodetectors with Copper-Phthalocyanine CUPC as top and Perylene-Tetracarboxylic Bis- Benzimidazole (PTCBI) as the bottom layer organic material. The bottom organic semiconductor layer work as both, charge transport layer and photon absorption layer. The top and bottom layer provides and heterojunction and a potential gradient enough to separate the photo generated excitons in to electrons and holes. The incident photons are absorbed in the two layers active layers giving an exciton. These excitons face a potential barrier at the CUPC-PTCBI heterojunction and separated into holes and electrons. The separated electrons are directed by the external applied electric field and thus give a high photocurrent.

Lateral organic photodetectors are simple to design and have low dark current. The photo response of these photo detectors is observed three orders higher in magnitude compare able to its dark response. The dual layer has an advantage of tuning the devices for different absorption wavelengths and were observed more stable comparable to vertical devices.

7961-03, Session 1

Design and optimization of a dedicated cone-beam CT system for musculoskeletal extremities imaging

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The design, initial imaging performance, and model-based optimization of a dedicated cone-beam CT (CBCT) scanner for musculoskeletal extremities imaging is presented. The system offers a compact scanner that complements conventional CT and MR modalities by providing sub-mm isotropic spatial resolution, the ability to image weight-bearing extremities, and capability for integrated real-time fluoroscopy and digital radiography. The scanner employs a flat-panel detector and a fixed anode x-ray source and has a field of view of ~(20x20x20) cm3. The gantry allows a “standing” configuration for imaging of weight-bearing lower extremities and a “sitting” configuration for imaging of upper extremities. Cascaded systems analysis guided the selection of x-ray technique (e.g., kVp, filtration, and dose) and system design (e.g., magnification factor), yielding input-quantum-limited performance at patient dose below 5 mGy (a factor of ~2-3 less than conventional CT). A magnification of 1.3 optimized tradeoffs between source and detector blur for a 0.5 mm focal spot. A custom antiscatter grid demonstrated significant reduction of artifacts without loss of contrast-to-noise ratio or increase in dose. Image quality in cadaveric specimens was assessed on a CBCT bench, demonstrating exquisite bone detail, visualization of intra-articular morphology, and soft-tissue visibility approaching that of diagnostic CT. The capability to image loaded extremities and conduct multi-modality CBCT / fluoroscopy with improved workflow compared to whole-body CT could be of value in a broad spectrum of applications. A clinical prototype is under construction for deployment in pilot study trials.

7961-04, Session 1

NIBIB programs for low cost imaging devices

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No abstract available

7961-05, Session 2

A laser-driven undulator x-ray source: simulation of image formation and dose deposition in mammography

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As overcoming some of the inherent limitations of x-ray tubes becomes increasingly harder it is important to consider new ways of x-ray generation and to study their applications in the field of medical imaging. In the present work a novel table-top sized x-ray source, developed by our group, that uses laser-accelerated electrons emitting x-ray radiation in a short period undulator has been investigated. This source

has the potential to deliver tunable and focusable x-rays with a very narrow spectral bandwith. The main purpose of this contribution is to characterize the performance of this source in the field of mammography and to compare it to that of conventional x-ray tubes. We simulated the whole imaging process from the electron beam dynamics through the generation of synchrotron radiation in the undulator up to the x-ray-matter interaction and detection in the mammographic setting. Thereby we demonstrate that it is possible to produce a stable laminar beam-profile suitable for a scanning geometry that greatly reduces the amount of the detected scattered radiation. A Monte-Carlo simulation of the absorption and scattering processes based on the Geant4 software toolkit has been developed that uses a high resolution voxel phantom of the female breast for the accurate simulation of mammography. It is shown that we can achieve a significant reduction of the dose necessary to achieve a certain image quality when compared to conventional x-ray tubes. Furthermore the application to dual-energy imaging and the possibility of noise reduction techniques are discussed.

7961-06, Session 2

The case for single-exposure angiography using energy-resolving photon-counting detectors: a theoretical comparison of signal and noise with conventional subtraction angiography

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The use of energy-resolving photon-counting (EPC) detectors creates an opportunity to develop new CT and radiographic procedures for material-specific imaging, such as single-pass angiography in which the injected-contrast signal is determined from an analysis of x-ray energies in a single exposure rather than the subtraction of a mask image from a post-contrast-injection image, as used in conventional digital subtraction angiography (DSA). Here we explore the theoretical implications of single-exposure angiography using EPC detectors by calculating the signal-to-noise ratio (SNR) in an iodine-specific image that could be determined using spectral methods and comparing the results with the corresponding SNR using conventional subtraction angiography for the same x-ray exposure. It is shown that with a 40-kV spectrum and 0.05 g/cm^2 of iodine in 20 cm of water, the iodine SNR (in a 1-mm^2 area) per square-root entrance exposure (R) is approximately 110 with DSA and 75 with EPC angiography. The best SNR for DSA is approximately 220 (at 70 kV) while the best EPC result is 90 (at 47 kV) for the same entrance exposure. This difference of approximately 2.5x is surprisingly small. The optimal kV for EPC angiography is lower than that for DSA. This would result in less x-ray scatter from the patient and might make the use of anti-scatter grids unnecessary. If this were true, the EPC method would have an SNR comparable to the best that could be achieved with DSA for the same exposure. In addition, EPC images would have no motion artifacts from imperfect registration and hence potentially superior diagnostic quality, and enable the development of novel dynamic studies.

7961-07, Session 2

Electron field emission PIC coupled with MCNPX simulation of a CNT-based flat-panel x-ray source

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A novel X-ray source based on carbon nanotubes (CNTs) field emitters is being developed as an alternative for medical imaging diagnostic technologies. The design is based on an array of millions of micro sized X-ray sources similar to the way pixels are arranged in flat panel displays. The trajectory and focusing characteristics of the field emitted electrons, as well as the X-ray generation characteristics of each one of the proposed micro-sized X-ray tubes are simulated. In this paper, the electron field emission is simulated using the OOPIC PRO particle-in-cell code. The X-ray generation is analyzed with the MCNPX Monte Carlo code. MCNPX is used to verify and optimize both the bremsstrahlung radiation energy spectra and angular distribution for each (1-8 μm) thick tungsten target. Also, different extracting, accelerating and focusing voltages, as well as different focusing structures and geometries of the micro cells are simulated using the OOPIC Pro particle-in-cell code. The electron trajectories, beam spot sizes, I-V curves, bremsstrahlung radiation energy spectra, angular distribution are all analyzed for each cell. The simulation results show that micro X-ray cells can be used to generate suitable electron currents using CNT field emitters and strike a thin tungsten target to produce a adequate bremsstrahlung spectrum. The shape and trajectory of the electron beam was modified using focusing structures. Modifications to the electron beam can help design a better X-ray transmission source.

7961-08, Session 2

CBCT Monte Carlo analysis: compensator design for scatter distribution minimization

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X-ray scatter has a significant impact on image quality in cone-beam CT (CBCT) with its effects including: CT number inaccuracy, streak and cupping artifacts, and loss of contrast. Compensators, such as bowtie filters, provide a method for not only decreasing the magnitude of the scatter distribution, but also reducing the structure found in the scatter distribution. Recent Monte Carlo (MC) simulations examining X-ray scatter in CBCT projection images have shown that the scatter distribution in x-ray imaging contains structure largely induced by coherent scattering. In order to maximize the reduction of x-ray scatter induced artifacts a decrease in both the magnitude and structure of the scatter distribution is sought through optimal compensator design. A flexible Monte Carlo (MC) model that allows for separation of scattered and primary photons has been created to simulate the CBCT imaging process using an extension of the EGSnrc MC code system. The CBCT MC model is used to investigate the effectiveness of different compensator designs, varying in shape and material composition, in decreasing the magnitude and structure of the object induced scatter distribution found in projection images used to reconstruct the CBCT volumetric image. The compensator designs on the scatter distribution are evaluated for different imaging locations (abdominal, prostate, and head) and viewing angles using a voxelized phantom created from CT data. The effect of each compensator on the amount of contamination photons in an open field is also investigated.

7961-10, Session 2

Optimization of the grid frequencies and angles in digital radiography imaging

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In order to reduce the grid artifacts, which are caused by using the antiscatter grid in obtaining x-ray digital images, we analyze the grid artifacts based on the multiplicative image formation model instead of the traditional additive model, and apply filters to suppress the artifact terms.

The artifact terms are aliases of the modulated terms from the harmonics of the grid frequency.

Hence, several filters are required to efficiently suppress the grid artifacts. However, applying filters also distort the original image that will be

recovered. If the distance between the origin and the center frequency of the artifact term is relatively large, then we can suppress the artifact term less distorting the original image. In this paper, by increasing the distances for a given sampling frequency of the image detector, we design antiscatter grids, which are good in terms of efficient grid artifact reduction. In order to design optimal grids, we formulate min-max optimization problems and provide optimal grid frequencies for a fixed grid angle with respect to the sampling direction of the image detector and optimal grid angles for a fixed grid frequency. We then propose using rotated grids with the optimal grid angles in digital radiography imaging. By applying band-rejection filters to the artifact, we can considerably reduce the grid artifacts when comparing to the traditional non-rotated grid case for real x-ray images.

7961-133, Session 2

Correlated-polarity noise reduction: feasibility of a new statistical approach to reduce image noise

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Reduction of image noise is an important goal in producing the highest quality medical images. Image noise can of course be reduced by increasing patient radiation exposure, but there are limitations on radiation exposure that are reasonable based on the benefit to be obtained from the examination. Various methods have been described in the literature for reducing image noise by means of image processing, both deterministic and statistical. Deterministic methods tend to degrade image resolution or lead to artifacts or non-uniform noise texture that does not look “natural” to the observer. Statistical methods, including Bayesian estimation, have been successfully applied to image processing, but may require more time-consuming steps of computing priors.

The approach described in this paper uses a statistical method we have developed in our laboratory to reduce image noise that is very fast. This approach, Correlated-Polarity Noise Reduction (CPNR), makes an estimate of the polarity of noise at a given pixel, and then subtracts a random variable from a normal distribution having a sign that matches the estimated polarity of the noise in the pixel. For example, if the noise is estimated to be positive in a given pixel, then a random number that is also positive will be subtracted from that pixel.

The CPNR method reduces the noise in an image by about 20% per iteration, with little impact on image resolution, few artifacts, and a final image noise that appears normal. Examples of the feasibility of this approach are presented in radiography and fluoroscopy.

7961-11, Session 3

A novel method to measure the zero-frequency DQE value of both linear and non-linear x-ray imaging systems

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A method is described that can be used to determine the zero-frequency DQE of both linear and non-linear x-ray imaging systems. The method requires acquisition of approximately five images of a thin copper foil that covers approximately half of the image field of view. The copper foil provides a known change in entrance exposure for a known spectrum. A simple theoretical expression was developed that accounts for the energy response of the detector and is used to linearize the system response. Combined with the image Wiener noise-power spectrum determined from the same images, the zero-frequency DQE value is determined. The theoretical basis of the method is described and experimental results show the zero-frequency DQE value agrees with a conventional analysis within a few percent for a CsI-based flat-panel detector. This method can be used to determine the zero-frequency DQE of systems even when the shape of the characteristic curve is linear, non-linear or unknown, and is simple enough to be implemented as part of routine testing in a clinical setting.

7961-12, Session 3

Use of sphere phantoms to measure the 3D MTF of FDK reconstructions

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To assess the resolution performance of modern CT scanners, a method to measure the 3D MTF is needed. Computationally, a point object is an ideal test phantom but is difficult to apply experimentally. Recently, Thornton et al. described a method to measure the directional MTF using a sphere phantom [1]. We tested this method for FDK reconstructions by simulating a sphere and a point object centered at (0, 0, 0) and (0, 0, 10 cm) and compared the directional MTF estimated from the reconstructed sphere with that measured from an ideal point object. While the estimated MTF from the sphere centered at (0, 0, 0) showed excellent agreement that from the point object, the estimated MTF from a sphere centered at (0, 0, 10 cm) had significant errors, especially along the fz axis. We found that this is caused by the long tails of the impulse response of the FDK reconstruction far off the central plane. We developed and tested a new method to estimate the directional MTF using the sphere data. The new method showed excellent agreement with the MTF from an ideal point object. Caution should be used when applying the original method in cases where the impulse response may be wide.

7961-13, Session 3

2D and 3D noise-power spectrum: Towards a standardized measurement method

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The noise power spectrum (NPS) is the reference metric for understanding the noise content in CT images as well as in evaluating image quality and system performance in different reconstruction planes.

However, although 2D and 3D NPS are being used more and more in MDCT and CBCT systems, no standardized 2D and 3D NPS methods have been proposed yet.

In order to obtain a robust method to extract the 2D and 3D NPS, the effects of the parameters that influence the NPS measurements were investigated. Simulations of the 2D and 3D NPS were computed while varying the region/volume of interest (ROI/VOI) size and overlap as well as the number of simulated noise images or volumes. Effects of the ROI/VOI background detrending and ROI/VOI positions were investigated on real noise images.

Measurements were performed on a homogenous phantom with a 64- and 128-MDCT. Reconstruction parameters were varied and images were reconstructed using a 512x512 matrix size in different reconstruction planes.

The size of the ROI/VOI strongly impacts the accuracy of the NPS metric. Low frequencies are cut off leading to a significant error when the ROI/VOI size is small. A ROI/VOI size of 64 or 128 pixels yields a local and accurate NPS. The statistical fluctuations affecting the NPS are reduced using a ROI/VOI overlap and a large number of noise images/volumes.

Although the structural noise is complex and difficult to remove, its effect can be minimized using a first-order detrending on subtracted image/volume data sets.

7961-14, Session 3

NPS comparison of anatomical noise characteristics in mammography, tomosynthesis, and breast CT images using power law metrics

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Digital mammography is the current standard for breast cancer screening, however breast tomosynthesis and breast CT (bCT) have been studied in clinical trials. At our institution, 23 women (BIRADS 4 and 5) underwent IRB-approved imaging by mammography, breast tomosynthesis, and bCT on the same day. Twenty data sets were used for analysis. The 2D noise power spectrum (NPS) was computed and averaged for each data set. The NPS was computed for different slice thicknesses of dx × N, where dx ≈ 0.3 mm and N=1-64, on the bCT data. Each 2D NPS was radially averaged, and the 1D data were fit using a power law function as proposed by Burgess: $NPS(f) = \alpha f^{\beta}$. The value of β was determined over a range of frequencies corresponding to anatomical noise, for each patient and each modality. Averaged over the 20 women (19 for bCT), for mammography β= 3.04 (0.23), for tomosynthesis β=2.81 (0.29), and for axial bCT β=1.83 (0.38). For sagittal bCT β=1.88 (0.38) and for coronal bCT β=1.72 (0.35). The computation of β versus slice thickness on the coronal bCT data set led to $\beta \approx 1.7$ for N=1, asymptotically reaching $\beta \approx 2.8$ for larger slice thickness. These results suggest that there is a fundamental difference in breast anatomic noise as characterized by β for thin slices (<2 mm) and for thicker slices. Tomosynthesis was found to have anatomic noise properties closer to mammography than breast CT, likely due to the relatively thick (~30 mm) slice sensitivity profile of tomosynthesis.

7961-15, Session 3

Imaging properties of the magnification factor in digital mammography by the generalized MTF (GMTF)

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The spatial resolution is particularly important in digital mammography where micro-calcifications may be a significant diagnostic feature. In magnification mammography, the resolution property is influenced by the geometrical unsharpness of the focal spot and the effective pixel size at each magnification factor. The aim of our study was to examine the effects of resolution for the magnification by breast thickness and lesion positioning by evaluating generalized modulation transfer function (GMTF) including the effect of focal spot, effective pixel size and the scatter. Measurements were performed for 10, 20, 30, and 40 mm PMMA thicknesses and magnification factors from 1.2 to 2.0 at intervals of 0.2. Images were acquired with the standard support platform for the clinical setting. Results demonstrate that the effect of the thickness and lesion positioning did not clearly appear for small focal spot. But a large focal spot did appreciably appear to the degradation of the resolution because focal spot blur dominated spatial resolution. Of note, the GMTF at the low spatial frequencies has a low frequency drop caused by scatters. This phenomenon is less with decreasing the PMMA thickness due to the lower scatter fraction. We also study the effect of lesion positioning in the same thickness. Although the effect of lesion positioning did not make an appreciable difference in images of the line pair test pattern, the GMTF did slightly change. These results can contribute in the effort to optimize the magnification with the thickness of the breast in clinical applications of digital mammography.

7961-16, Session 4

Predictive models for observer performance in CT: applications in protocol optimization

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The relationship between theoretical descriptions of imaging performance (Fourier-based) and the performance of real human observers was investigated for detection tasks in multi-slice CT. The detectability index for the Fisher-Hotelling model observer and non-prewhitening model observer (with and without internal noise and eye filter) was computed using: 1) the measured modulation transfer function (MTF) and noise-power spectrum (NPS) for CT; and 2) a Fourier description of imaging task. Based upon CT images of human patients with added simulated lesions, human observer performance was assessed via an observer study in terms of the area under the ROC curve (Az). The degree to which the detectability index correlated with human observer performance was investigated and results for the non-prewhitening model observer with internal noise and eye filter (NPWE) were found to agree best with human performance over a broad range of imaging conditions. Results provided initial validation that CT image acquisition and reconstruction parameters can be optimized for observer performance rather than system performance (i.e., contrast-to-noise ratio, MTF, and NPS). The NPWE model was further applied for the comparison of FBP with a novel model-based iterative reconstruction algorithm to assess its potential for dose reduction across various CT imaging tasks.

7961-17, Session 4

High-order noise analysis for low dose iterative image reconstruction methods: ASIR, IRIS, and MBAI

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Iterative reconstruction technology (IRT) has been shown to suppress noise significantly in low dose CT imaging.

However, medical doctors hesitate to accept this new technology because visual impression of IRT images are different from full dose FBP images. Most common noise measurements are mean and standard deviation of homogeneous region on the image that don't provide enough characteristics of noise statistics when probability density function becomes non-Gaussian. In this study, we measure L-moments of intensity values of images acquired at 10% of normal dose and reconstructed by IRT methods of two state-of-art clinical scanners (i.e., GE HDCT and Siemens DSCT °ash) by keeping dosage level identical to each other. The high and low dose scan (i.e., 10% of high dose) were acquired from each scanner and L-moments of noise patches were calculated for the comparison.

7961-18, Session 4

Adaptive iterative reconstruction (AIR)

H. K. Bruder, R. Raupach, M. Sedlmair, J. Sunnegardh, K. Stierstorfer, T. Flohr, Siemens Healthcare (Germany)

We present an Adaptive Iterative Reconstruction scheme (AIR) which applies to statistical IR based on the Gaussian noise model as well as to signal-weighted algebraic IR. Any iterative reconstruction consists of two parts: the raw-data loop with repeated forward- and backprojec-tions, and image regularization which controls the image noise characteristics and is responsi-ble for contrast-dependent sharpness. We show that both regularization and statistical data weighting in case of statistical IR with data-dependent Gaussian noise can be translated into non-linear image processing. We developed an iterative, nonlinear image filter,

which is based on a non-isotropic noise model derived from the input raw data.. The raw-data loop reduces image artifacts due to the non-exactness of the reconstruction,The raw data iterations, however, do not reduce image noise. The input data are pre-filtered such that the raw-data iteration loop is kept neutral in terms of noise and the output image volume has a well defined image texture controlled by a pre-selected CT convolution kernel. Image noise is reduced and image characteristics are adjusted in the succeeding iterative image filter loop. We account for non-isotropic image noise due to the statistical uncertainty of the projection data by scaling the filter strength with the estimated local, non-isotropic noise variances and apply priors as a function of local, non-isotropic contrast-to-noise ratio. The benefit of the proposed method is the fast raw-data iteration with only 2-3 loops in contrast to true statistical iterative recon-struction requiring 10 iterations and more. Based on Dual Source Flash cardiac data we show that reconstruction artifacts are removed after 2 iterations. Based on simulation and clinical data, we show, that the noise characteristics and sharpness-to-noise obtained with the new method can be approximated with a high precision to that obtained with classical IR based on statistical data weighting.

7961-19, Session 4

Fast iterative image reconstruction using sparse matrix factorization with GPU acceleration

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Fast and efficient, iterative image reconstruction is highly demanded for state-of-art high-resolution imaging systems.

An accurate system matrix that defines the mapping from the image space to the data space is the key to high-resolution image reconstruction. However, an accurate system matrix is often associated with a high computation cost and huge storage requirement. Here we present a method to address this problem by using sparse matrix factorization and GPU acceleration. We factor the accurate system matrix into three sparse matrices: a sinogram blurring matrix, a geometric projection matrix, and an image blurring matrix. The geometrical projection matrix is precomputed based on a simple line integral model, while the sinogram and image blurring matrices are estimated by minimizing the difference between the factored system matrix and the original system matrix. The resulting factored system matrix has much less number of nonzero elements than the original system matrix, which substantially reduces the storage and computation cost. The smaller size also allows an efficient implementation of the forward and back projectors on GPUs, which has limited amount of memory. Our simulation studies show that the proposed method can dramatically reduce the computation cost of high-resolution iterative image reconstruction. The proposed technique is applicable to image reconstruction for different imaging modalities, including x-ray CT, PET, and SPECT.

7961-20, Session 4

Precision of hepatic CT image quantifications: a comparative study of conventional (FBP) and iterative reconstruction algorithms (ASiR and MBIR)

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The increase in Hounsfield Unit and the contrast after the injection of contrast media is of quantitative interest in hepatic CT imaging. However, the precision of this quantitative measurement may be susceptible to imaging techniques such as dose and reconstruction algorithm. To determine their impact, we scanned an iodinated liver phantom with acquisition protocols of different dose levels, kVps, and pitches, reconstructed images using different algorithms, and calculated the precision of each protocol accordingly. Results showed an improved precision with increasing dose, and a possible 50% to 90% dose reduction when using MBIR instead of FBP for reconstruction. To our knowledge, this is the first investigation of the dependence of precision on protocols for contrast related quantification in hepatic CT image.

7961-21, Session 4

An iterative dual energy CT reconstruction method for a K-edge contrast material

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We present and evaluate an iterative dual energy CT reconstruction algorithm for a K-edge contrast material in microCT imaging. This allows improved discrimination of contrast enhanced structures such as vasculature from surrounding bony structures. The energy dependence of the attenuation is modeled by decomposing the linear attenuation coefficient into three basis functions. Any material without a K-edge in the imaging energy range can be modeled by two basis functions describing the Compton scatter and the photoelectric effect respectively. A K-edge material is described by using its mass attenuation coefficient as third basis function. In the reconstruction the basis function coefficients are determined by maximizing the likelihood. The relative weights of the Compton and photoelectric components are constrained to those of expected materials to reduce the number of unknowns to two per voxel.

The proposed method is validated on simulated and real microCT projections. The presented method was found to perform better than a typical post-reconstruction approach with respect to beam-hardening and noise at the expense of increased computation time.

7961-22, Session 5

Novel synthesis of large area ZnTe:O films for high resolution imaging applications

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Oxygen doped ZnTe is a bright scintillator with one of the highest X-ray conversion efficiencies with a high density of 6.4 gm/cc and a fast decay time of ~1 μs with negligible afterglow. These properties make it an ideal choice for wide range of X-ray imaging applications in biology and medicine. With an emission wavelength of 680 nm it is ideally suited for use with silicon imagers such as CCDs and CMOS. Our previous work has demonstrated efficacy of fabricating columnar ZnTe:O films using hot wall evaporation (HWE) [1]. In this paper we report a new co-evaporation process where the oxygen dopant concentration in the evaporated film is controlled by simultaneous evaporation of ZnO and ZnTe charge. This process is well suited for fabricating large area structured thin films of ZnTe:O in an efficient manner. To date we have fabricated as large as 40 cm2 area films measuring 50 to 500 μm in thickness. These films have exhibited 125% brighter emission than the standard Kodak Min-R 2000 Gd2O2S:Tb screen. Scanning Electron Microscope (SEM) images reveal oriented columnar structure, which is critical for achieving high spatial resolution. Details of the film fabrication, characterization, and imaging performance will be discussed in the paper.

7961-23, Session 5

12-inch-wafer-scale CMOS active-pixel sensor for digital mammography

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This paper describes the development of an active-pixel sensor (APS) panel, which has a field-of-view of 23.1 x 17.1 cm and features 70-µm-sized pixels arranged in a 3300 x 2442 array format, for digital mammographic applications. The APS panel was realized on 12-inch wafers based on the standard complementary metal-oxide-semiconductor (CMOS) technology without physical tiling processes of several small-area sensor arrays. Electrical performance of the developed panel is described in detail. For mammographic imaging, the optimized CsI:Tl scintillator is experimentally determined by being combined with the developed panel and analyzing imaging characteristics, such as modulation-transfer function, noise-power spectrum, detective quantum efficiency, image lag, and contrast-detail analysis.

7961-24, Session 5

Noise performance limits of advanced x-ray imagers employing poly-Si-based active pixel circuit architectures

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A decade after the clinical introduction of active matrix flat-panel imagers (AMFPIs), the performance of this technology continues to be limited by the relatively large additive electronic noise of these systems - resulting in significant loss of detective quantum efficiency (DQE) under conditions of low exposure or high spatial frequencies. An increasingly promising approach for overcoming such limitations involves the incorporation of in-pixel amplification circuits, based on low-temperature polycrystalline silicon (poly-Si) thin-film transistors (TFTs). In this study, the limiting noise performance of such circuits is explored by means of sophisticated SPICE circuit simulations and cascaded systems modeling. Measurements of transfer and output characteristics, as well as current noise densities, from individual, variable-geometry, poly-Si TFT test devices, are used to extract model parameters suitable for these simulations. Selected device models are extended with additional controlled current or voltage sources, corresponding to thermal, shot or 1/f noise. The input stimuli and operating-point-dependent scaling of these sources are derived from the measured current noise densities (for 1/f noise), or fundamental equations (for thermal and shot noise). In this presentation, estimates of expected noise performance, based on simulations performed with selected circuits and operating conditions, will be presented. The noise and DQE performance of a variety of circuits and operational modes will be compared - with the objective of guiding the development of future generations of active pixel imager prototypes. The results suggest that input-quantum-limited operation is possible for exposures significantly lower than those for existing AMFPIs. Research supported by NIH grant R01-EB000558.

7961-25, Session 5

Characterization and comparison of lateral amorphous semiconductors with embedded Frisch grid detectors on 0.18µm CMOS processed substrate for medical imaging applications

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Amorphous semiconductors are commonly used as detectors in indirect and direct conversion X-ray imaging. This is because they allow for uniform large area panels to be constructed that can be used for mammography and chest radiography. Amorphous panels, however, due to charge trapping and asymmetrical carrier mobility are prone to image ghosting, slow speed of operation, and therefore cannot be used in real time fluoroscopy or cone beam CT scan applications.

We report the preliminary results from a small prototype imaging system that combines a lateral metal-semiconductor-metal (MSM) design on a 0.18um TSMC CMOS process with thin layers of amorphous semiconductors as the detector. The lateral design is demonstrated with 40um x 40um pixel pitches. In some pixels are also embedded a lateral Frisch grid that aims to provide unipolar charge sensing to speed up the charge collection. In addition, the CMOS silicon backplane allows for the PPS driving transistors to be smaller, faster, and of lower noise than a-Si backplanes.

Given the falling costs of the 0.18um process, the availability of wafer scale integration and the potential to incorporate large amounts of pixel and readout circuitry on the substrate we have the opportunity to cheaper and higher performance X-ray imaging devices. In this work we investigate the difficulty of integrating amorphous semiconductors with an existing CMOS fabrication process to construct a PPS array that can be used as a photo detector for high speed and low noise medical imaging operations such as mammography tomosynthesis, low dose fluoroscopy and cone-beam computed tomography (CT).

7961-26, Session 5

Low noise TFT arrays for digital x-ray imaging detectors

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A new and novel detector structure is now being investigated to minimize the readout noise of large area TFT arrays. A conventional TFT panel consists of orthogonal arrays of gate lines and data lines. The parasitic capacitance from the crossover of these lines results in a sizable data line capacitance. During image readout, the thermal noise of the charge integrator is greatly magnified by the ratio of the data line capacitance to the feedback capacitor of the charge amplifier. The swinging of the gate voltage will also inject charges in and out of the imaging holding pixel capacitors and contribute to the switching noise in the readout image. By redesigning the layout of the TFT arrays and by coupling linear light source to the bottom side of the TFT array in the same direction as the gate lines, the crossover of gate lines and data lines can be avoided and the data line capacitance is greatly reduced. Instead of addressing each row of transistors by the switching of the gate control voltage, linear light source with collimators are used to optically switch on and off the amorphous silicon transistors. The transistor switching noise from the swinging of the gate voltages is reduced. By minimizing the data line capacitance and avoiding the swinging of the gate control voltage, the basic TFT readout noise is minimized and lower dose x-rays images can be achieved. This design is applicable to both Direct Conversion and Indirect Conversion panels. Some recent results will be presented.

7961-27, Session 6

Performance characterization of a silicon strip detector for spectral computed tomography utilizing a laser testing system

C. Xu, M. Danielsson, S. Karlsson, H. Bornefalk, Royal Institute of Technology (Sweden)

A new generation of silicon strip detector with sub-millimeter pixel size operated in single photon-counting mode has been developed for use in spectral computed tomography (CT). Edge-on geometry is adopted to partially offset the low detection efficiency of silicon for high energy x rays used in conventional CT imaging. An ultrafast application specific integrated circuit (ASIC) specially designed for fast photon-counting application is used to process the pulses. The energy of each event can be obtained by comparing with 8 separate thresholds.

The initial test results show that an excellent noise performance can be achieved for this detector prototype. The performance of this photon-counting detector has also been tested by using a picosecond pulsed laser system. The use of a fast laser pulse to inject energy into the detector simulates x-ray interactions. The energy of the laser pulse can

be adjusted to generate the same number of charge carriers in the silicon detector as a x-ray photon does in the energy range of CT imaging after taking into account the loss of laser energy and quantum efficiency of e-h pair generation in silicon detector. The laser testing results indicate a good energy-discriminating capability of the detector.

7961-28, Session 6

Quantum-counting CT in the regime of count-rate paralysis: introduction of the pile-up trigger method

S. G. Kappler, S. Hoelzer, E. Kraft, K. Stierstorfer, T. Flohr, Siemens Healthcare (Germany)

The application of quantum-counting detectors in clinical Computed Tomography (CT) is challenged by extreme X-ray fluxes provided by modern high-power X-ray tubes. Scanning of small objects or sub-optimal patient positioning may lead to situations where those fluxes impinge the detector without attenuation. Even in operation modes optimized for high-rate applications, with small pixels and high bias voltage, CdTe/CdZnTe detectors deliver pulses in the range of several nanoseconds. This can result in severe pulse pile-up causing detector paralysis and ambiguous detector signals. To overcome this problem we introduce the pile-up trigger, a novel method that provides unambiguous detector signals in rate regimes, where classical rising-edge counters run into count-rate paralysis. We present detailed CT image simulations, assuming ideal sensor material not suffering from polarization effects at high X-ray fluxes. This way, we demonstrate the general feasibility of the pile-up trigger method and quantify resulting imaging properties such as contrasts, image noise and dual-energy performance in the high-flux regime of clinical CT devices.

7961-29, Session 6

6-Li enriched Cs2LiYCl6:Ce based thermal neutron detector coupled with CMOS solid-state photomultipliers for a portable detector unit

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For detecting neutrons, 3-He tubes provide sensitivity and a unique capability for detecting and discriminating neutron signals from background gamma-ray signals. A solid-state scintillation-based detector provides an alternative to 3-He for neutron detection. A real-time, portable, and low cost thermal neutron detector has been constructed from a 6-Li enriched Cs2LiYCl6:Ce (CLYC) scintillator crystal coupled with a CMOS solid-state photomultiplier (SSPM). These components are fully integrated with a miniaturized multi-channel analyzer (MCA) unit for calculation and readout of the counts and count rates.

CLYC crystals and several other elpasolites including Cs2LiLaCl6:Ce (CLLC) and Cs2LiLaBr6:Ce (CLLB) have been investigated for their unique properties in detecting neutrons and discriminating gamma ray events along with providing excellent energy resolution comparable to NaI(Tl) scintillators. CLYC's slower rise and decay time for neutrons (70ns and 900ns respectively) relative to a faster rise and decay time for gamma ray events (6ns and 55ns respectively) allows for pulse shape discrimination in mixed radiation fields.

Light emissions from CLYC crystals are detected using an array of avalanche photodiodes referred to as solid-state photomultipliers. SSPMs are binary photon counting devices where the number of pixels activated is directly proportional to the light output of the CLYC scintillator which is proportional to the energy deposited from the radiation field. SSPMs can be fabricated using standard CMOS processes and inherently contain the low noise performance associated with ordinary photomultiplier tubes (PMT) while providing a light and compact solution for portable neutron detectors.

7961-30, Session 6

Integration of an amorphous silicon passive pixel sensor array with a lateral amorphous selenium detector for indirect conversion x-ray imaging applications

K. Wang, Univ. of Waterloo (Canada) and Thunder Bay Regional Research Institute (Canada); M. Y. Yazdandoost, K. Shin, F. Chen, S. H. Majid, S. Abbaszadeh, R. Keshavarzi, M. Mayer, K. S. Karim, Univ. of Waterloo (Canada)

In large area diagnostic X-ray imaging, there are two detection mechanisms namely direct conversion and indirect conversion. Besides the drawback of required high voltage, a direct conversion detector based on a thick amorphous selenium (a-Se) vertical multilayer structure also suffers from temporal artifacts such as image lag and ghosting. Moreover, low K-edge energy of a-Se limits its applications in high energy imaging such as dental imaging and CT. The start-of-the-art approach is to overlay a scintillator atop an amorphous silicon photodiode and amorphous silicon (a-Si:H) switching thin film transistor (TFT) through indirect conversion. However, speed of response, dark current, fill factor, and signal to noise ratio require further improvements.

In addition to low dark current, a-Se also demonstrates strong absorption at short wavelengths from green to ultraviolet. Therefore, it holds considerable promise for indirect conversion X-ray imaging. The predictable merits of such an imager will be high sensitivity, low noise, and large dynamic range.

Previously, we reported on a single-pixel detector based on a lateral a-Se metal-semiconductor-metal (MSM) structure [1-3]. This work is the effort towards a prototype of an indirect conversion X-ray imaging array utilizing lateral selenium. Instead of a structurally-sophisticated photodiode, a lateral a-Se MSM photodetector is employed which can be easily integrated with an a-Si:H TFT passive pixel sensor (PPS) array to obtain indirect conversion X-ray imaging. The 64×64 PPS prototype array based on lateral a-Se MSM photodetectors is fabricated and characterized along with discussion of the results.

7961-31, Session 6

Simulation of one-dimensionally polarized X-ray semiconductor detectors

K. J. Engel, C. Herrmann, Philips Research (Germany)

We simulated pixelated X-ray semiconductor detectors (="direct converters") containing an inhomogeneous electric field parallel to the depth axis, as caused for example by layers of ionized dopants or trapped charge carriers, and examine drift times and pulse shapes for various degrees of static polarization. Furthermore, spectral detector responses are studied with a Monte-Carlo simulation of X-ray dose deposition, followed by an analytical calculation of the pixel-wise charge collection. The analytical model considers charge sharing in form of a lateral charge cloud extension during drift in the electric field. We find that generally detector performance degrades if the effective doping concentration approaches a critical limit. For some special cases of acceptor doping, however, we find even an improvement of detector performance compared to the intrinsic case.

7961-32, Session 6

Electrical interface characteristics (i-v), optical time of flight measurements, and the x-ray (20 kev) signal response of amorphous-selenium/crystalline-silicon heterojunction structures

D. M. Hunter, Sunnybrook Health Sciences Ctr. (Canada); C. A. Ho, Univ. of Toronto (Canada); G. Belev, Canadian Light Source (Canada); G. De Crescenzo, Thunder Bay Regional Research Institute (Canada); M. J. Yaffe, Sunnybrook Health Sciences Ctr. (Canada)

We have investigated the dark current, optical TOF (time of flight) properties, and the X-ray response of amorphous-selenium (a-Se)/ crystalline-silicon (c-Si) heterostructures for application in digital radiography. The structures have been studied to determine if an x-ray generated electron signal, created in an a-Se layer, could be directly transferred to a c-Si based readout device such as a back-thinned CCD (charge coupled device). A simple first order band-theory of the structure indicates that x-ray generated electrons should transfer from the a-Se to the c-Si, while hole transfer from p doped c-Si to the a-Se should be blocked, permitting a low dark signal as required. The structures we have tested have a thin metal bias electrode on the x-ray facing side of the a-Se which is deposited on the c-Si substrate. The heterostructures made with pure a-Se deposited on epitaxial p doped (5x10^14 cm^-3) c-Si exhibited very low dark current of 15 pA cm^-2 at a negative bias field of 10 V micrometre^-1 applied to the a-Se. The optical TOF (time of flight) measurements show that the applied bias drops almost entirely across the a-Se layer and that the a-Se hole and electron mobilities are nominal. The x-ray signal measurements demonstrate the structure has the expected x-ray quantum efficiency. We have made a back-thinned CCD coated with a-Se and although it does not work fully as an imaging device, it contains regions which do work properly. Improved understanding of the a-Se/c-Si interface and preparation methods should lead to properly functioning devices.

7961-33, Session 7

Photoacoustic imaging of the breast

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We hypothesize that hemoglobin, a strong optical absorber, may be used as a sensitive biomarker for breast-cancer-stimulated angiogenesis. Ubiquitous levels of scatter, however, mask the optical absorption patterns from breast tissue lying deeper than a few millimeters beneath the skin surface. It is for this reason that breast transillumination has not demonstrated clinical efficacy. However, optical absorption can be localized with submillimeter spatial resolution through several centimeters of breast tissue by stimulating and recording photoacoustic interactions that take place in regions of optical absorption. We will describe a 3D, photoacoustic computed tomography (PCT) scanner based on an array of transducers conformed to a hemispherical surface, and a laser-illumination source operated in the near infrared to visualize the 3D distribution of hemoglobin in the breast. Initial results indicate that hemoglobin within vascular anatomy can be visualized to a depth of 4 cm in vivo without the use of contrast agents. Image acquisition time is less than 30 seconds, which opens the door to dynamic contrast-enhanced PCT following injection of indocyanine green, an FDA-approved organic dye used for blood pool imaging and quantifying cardiac output.

7961-34, Session 7

Comparison of 3D and 2D breast density estimation from synthetic ultrasound tomography images and digital mammograms of anthropomorphic software breast phantoms

P. R. Bakic, The Univ. of Pennsylvania Health System (United States); C. Li, E. West, M. A. Sak, Karmanos Cancer Institute (United States); S. Gavenonis, The Univ. of Pennsylvania Health System (United States); N. Duric, Karmanos Cancer Institute (United States); A. D. Maidment, The Univ. of Pennsylvania Health System (United States)

Three-dimensional (3D) breast density descriptors based upon the sound-speed estimates from ultrasound tomography (UST) have been calculated in synthetic images of 20 anthropomorphic software breast phantoms. Each phantom simulated a 450 ml breast with volumetric percent density (PD) values between 10% and 50%. These UST based density descriptors have been validated by calculating their correlation with the two-dimensional (2D) PD estimated from synthetic digital mammograms (DM) of corresponding phantoms. The 2D PD values were estimated interactively by a clinical breast radiologist using Cumulus software. We also compared the UST based descriptors and 2D PD estimates with the ground truth 3D PD values available from the phantoms.

The UST based breast density descriptors showed a high correlation with the 2D PD estimates, as evidenced by the Pearson correlation coefficient of 0.87. In addition, both the UST based descriptors and 2D PD estimates showed high correlation with the ground truth 3D PD, with correlation coefficients of 0.97 and 0.91, respectively.

Our preliminary study of 3D descriptors of breast density calculated from UST images showed promise for non-invasive estimation of breast density. This preliminary study was based upon the analysis of synthetic images from 20 anthropomorphic software phantoms; the analysis of a larger number of phantoms is ongoing. Use of phantoms has proven useful in comparing breast density descriptors from synthetic UST and DM images.

7961-35, Session 7

The effect of characteristic x-rays on the spatial and spectral resolution of a CZT based detector for breast CT

S. J. Glick, Univ. of Massachusetts Medical School (United States); C. S. Didier, Massachusetts Institute of Technology (United States)

In an effort to improve the early stage detection and diagnosis of breast cancer, a number of research groups have been investigating the use of x-ray computerized tomography (CT) systems dedicated for use in imaging the breast. Preliminary results suggest that dedicated breast CT systems can provide improved visualization of 3D breast tissue as compared to conventional mammography. However, current breast CT prototypes that are being investigated have limitations resulting in less than desirable spatial resolution, lesion contrast, and signal-to-noise (SNR) ratio. Another option is a CT breast imaging system that uses a cadmium zinc telluride (CZT) based detector operating in a photon counting mode. The development of a photon counting CZT detector for breast CT is very challenging. Two effects that can substantially penalize image quality are charge diffusion of electrons as they traverse towards the pixelized detector, and a limited count rate capability. These degrading effects can be reduced by using a thinner CZT crystal. This paper uses a Monte Carlo simulation to evaluate the effect of characteristic x-rays on spatial and spectral resolution for a CZT detector used for breast CT. It is concluded that using CZT of 400-500 micron

thickness would not cause significant differences in spatial or spectral resolution, nor in stopping power as compared to using CZT with thickness 2-3 mm.

7961-36, Session 7

Analysis of multilayer and single layer x-ray detectors for contrast-enhanced mammography using imaging task

N. Allec, S. Abbaszadeh, K. S. Karim, Univ. of Waterloo (Canada)

A multilayer (single-shot) detector has previously been proposed for contrast-enhanced mammography. The multilayer detector has the benefit of avoiding motion artifacts due to simultaneous acquisition of both high and low energy images. A single layer (dual-shot) detector has the benefit of better control over the energy separation since the incident beams can be produced and filtered separately. In this paper the performance of the multilayer detector is compared to that of a single layer detector using an ideal observer detectability index which is determined from an extended cascaded systems model and a defined imaging task. The detectors are assumed to have amorphous selenium direct conversion layers, however the same theoretical techniques used here may be applied to other types of integrating detectors. The anatomical noise caused by variation of glandularity within the breast is known to dominate the noise power spectrum at low frequencies due to its inverse power law dependence and is thus taken into account in our model to provide an accurate estimate of the detectability index. The conditions leading to the optimal detectability index, such as tube voltage, filtration, and weight factor are reported for both detector designs.

7961-37, Session 7

Optimization of mammography with respect to anatomical noise

E. Fredenberg, B. Cederström, Royal Institute of Technology (Sweden); B. Svensson, Sectra Mamea AB (Sweden); M. Danielsson, Royal Institute of Technology (Sweden)

Beam quality optimization in mammography traditionally considers detection of a target obscured by quantum noise on a homogenous background. It can be argued that this scheme does not correspond well to the clinical imaging task because real mammographic images contain a complex superposition of anatomical structures. We present results from an observer model optimization that takes also the anatomical background noise into account. Within this framework, the detectability of tumors and microcalcifications behaves very differently with respect to beam quality and dose. The results for microcalcifications are similar to what the traditional optimization methods yield, which is to be expected since quantum noise dominates over anatomical noise at high spatial frequencies. For large tumors, however, low-frequency anatomical noise is the limiting factor. Because these variations have similar energy dependence as the tumor contrast, optimal x-ray energy is significantly higher and the useful energy region wider than traditional methods suggest. Exposure settings used clinically are therefore often sub-optimal for this imaging task. Furthermore, since quantum noise constitutes only a small fraction of the noise, dose can be reduced substantially without sacrificing tumor detectability. How these findings affect optimization of the mammographic imaging task as a whole is not obvious, but some implications and possible scenarios are discussed.

7961-38, Session 7

Issues in characterizing anatomic structure in digital breast tomosynthesis

B. A. Lau, I. S. Reiser, R. M. Nishikawa, The Univ. of Chicago (United States)

Normal mammographic backgrounds have power spectra that can be described using a power law P(f)=C/f^ β, where β ranges from 1.5 to 4.5. This anatomical noise can be the dominant noise source in a radiograph. Many researchers are characterizing anatomical noise by β, which can be measured from an image. We have calculated β for tomosynthesis projection view and reconstructed images, and we found that ROI size affects the magnitude of β. We used two different ROI sizes (1.28cm x 1.28cm and 3.2cm x 3.2cm), and we found that the larger ROI size tended to reduce the value of beta in the projection images. Further we found that β values in a single case are not normally distributed, and thus the summary metric (mean, median, and geometric mean) can differ by about 7%. These β values change rapidly across a single projection view; however, despite the variation across the breast, different sampling schemes (which includes the amount of overlap between ROIs and the starting location for sampling) yielded average β values with less than 1% variation. Based on preliminary data, the particular location and number of samples used to calculate β does not matter as long as the whole image is spanned, but the size of the ROI and the summary index must be chosen carefully. Studies are ongoing to validate these results.

7961-39, Session 7

Evaluation of photon-counting spectral breast tomosynthesis

N. Dahlman, E. Fredenberg, Royal Institute of Technology (Sweden); M. Åslund, B. Svensson, Sectra Mamea AB (Sweden); F. Diekmann, Charité Universitätsmedizin Berlin (Germany); M. Danielsson, Royal Institute of Technology (Sweden)

We have designed a mammography system that for the first time combines photon-counting spectral imaging with tomosynthesis. The present study is a comprehensive physical evaluation of the system; tomosynthesis, spectral imaging, and the combination of both are compared using an ideal-observer model that takes anatomical noise into account. Predictions of signal and noise transfer through the system are verified by 3D measurements of MTF and NPS. Images acquired with the system, e.g. specimen, clinical, and phantom images, are discussed in view of the model predictions.

7961-40, Session 8

Tomosynthesis imaging with 2D scanning trajectories

K. B. Khare, B. E. Claus, J. W. Eberhard, GE Global Research (United States)

Tomosynthesis imaging in chest radiography provides volumetric information with the potential forimproved diagnostic value when compared to the standard AP or LAT projections. In this paper we explore the image quality benefits of 2D scanning trajectories when coupled with advanced image reconstruction approaches. It is intuitively clear that 2D trajectories provide projection data that is more complete in terms of Radon space filling, when compared with conventional tomosynthesis using a linearly scanned source. Incorporating this additional information for obtaining improved image quality is however not a straightforward problem. The typical tomosynthesis reconstruction algorithms are based on direct inversion methods e.g. Filtered Backprojection (FBP) or iterative algorithms that are variants of the Algebraic Reconstruction Technique (ART). The FBP approach is fast and provides high frequency details in the image but at the same time introduces streaking artifacts degrading the image quality. The iterative methods based on ART can reduce the image artifacts by using image priors but suffer from a slow convergence rate, thereby producing images lacking high frequency details in practical reconstruction times. In this paper we propose using a fast converging optimal gradient iterative scheme that has advantages of both the FBP and ART-based methods in that it produces images with high frequency

details while reducing the image artifacts. We show that using favorable 2D scanning trajectories along with the proposed reconstruction method has the advantage of providing improved depth information for structures such as the spine and potentially producing images with more isotropic resolution.

7961-41, Session 8

Dynamic reconstruction and rendering of 3D tomosynthesis images

S. Ng, P. A. Ringer, Real-Time Tomography, LLC (United States); A. D. Maidment, P. R. Bakic, The Univ. of Pennsylvania Health System (United States); J. Kuo, S. G. Fallows, Real-Time Tomography, LLC (United States)

Digital breast tomosynthesis (DBT) is an emerging three-dimensional (3D) imaging modality in which 9 to 49 x-ray projection images are acquired over a limited angular range, typically 15° to 60°, while the breast is held in compression. Current DBT systems then produce datasets consisting of hundreds of images per patient at fixed resolution and spacing. To address the need for the high-throughput necessary for DBT screening and diagnosis, we have developed a reconstruction methodology that allows dynamic reconstruction and rendering (DRR) of arbitrary planes through the breast volume in real-time on a dedicated high-end PC-based graphics processor unit (GPU). A back-projection and filtered (BPF) algorithm has been implemented that allows nearly instantaneous reconstruction of tomographic images using GPU hardware that is essentially off-the-shelf and readily available. The combination of DRR and BPF provides reconstruction-on-demand, the observer alters the specification of the plane of reconstruction (by changing the position or size of the plane through the CPU-based GUI) or the reconstruction parameters while the displayed reconstructed image is updated in real-time. Thus, DRR allows arbitrary reconstruction without adversely impacting either storage or speed.

7961-42, Session 8

Adaptive diffusion regularization for enhancement of microcalcifications in digital breast tomosynthesis (DBT) reconstruction

Y. Lu, H. Chan, J. A. Fessler, L. M. Hadjiiski, J. Wei, M. M. Goodsitt, Univ. of Michigan (United States)

Detection of microcalcifications in digital breast tomosynthesis (DBT) is challenging because of the large breast volume to be searched for small, subtle signals and the noise in the reconstructed volume. We developed an adaptive diffusion (AD) regularization method that can differentially regularize noise and potential signal regions during reconstruction based on local contrast-to-noise ratio (CNR) information. This method applies different degrees of regularity, as guided by a CNR map for each DBT slice within the image volume, by using local CNR values to define the local diffusion coefficients such that potential signals will be preserved while noise is suppressed. DBT scans of an American College of Radiology phantom and the breast of a subject with biopsy-proven calcifications were acquired with a GE prototype DBT system at 21 angles in 3° increments over a ±30° range. Simultaneous algebraic reconstruction technique (SART) was used for DBT reconstruction. The AD regularization method was compared to the non-convex total p-variation (TpV) method and SART with no regularization (NR) in terms of the CNR and the full width at half maximum (FWHM) of the central gray-level line profile in the focal plane of a calcification. The results demonstrated that the SART regularized by the AD method enhanced the CNR and preserved the sharpness of microcalcifications compared to reconstruction without regularization. The AD regularization was superior to the TpV method for subtle microcalcifications in terms of the CNR while the FWHM was comparable. The AD regularized reconstruction has the potential to improve the CNR of microcalcifications in DBT for human or machine detection.

7961-43, Session 8

Comparison of model-observer and human-observer performance for breast tomosynthesis: effect of reconstruction and acquisition parameters

M. Das, H. C. Gifford, Univ. of Massachusetts Medical School (United States)

The problem of optimizing the acquisition and reconstruction parameters for breast cancer detection with DBT is becoming increasingly important due to its potential approval for clinical use. The optimum acquisition parameters likely depend on signal type (mass or microcalcification [MCs]), size, and contrast. The total acquisition dose and the intended reconstruction method are other factors. The complexity of this multidimensional optimization is compounded by the nature of the breast structure, which is difficult to implement in a mathematical model. Thus, human-observer studies, although very time consuming, remain as the gold standard for evaluating DBT for clinically realistic detection tasks. Our aim is to develop a mathematical model observer that can reliably predict the performance of human observers with DBT images. To begin, we implemented a channelized nonprewhitening model observer for MC detection that is based on a signal-known-exactly-but-variable task paradigm. The performance of this observer has been compared with the average performance of human observers from a previous LROC study. This comparison considered three different acquisition dose levels and two reconstruction methods. The performance of model observers that localize malignancies based on a visual-search paradigm will be discussed at the conference.

7961-44, Session 8

A second pass correction method for calcification artifacts in digital breast tomosynthesis

K. Erhard, M. Grass, T. Nielsen, Philips Research (Germany)

Digital breast tomosynthesis (DBT) aims for improving the diagnosis of breast cancer and reducing the false positive rates compared to 2D mammography. Current acquisition methods for digital breast tomosynthesis take 10-30 X-ray projections over an angular range of 15-60 degree. In contrast to fully three-dimensional modalities such as breast CT, DBT is affected by the limited angular range in a decreased depth resolution. Therefore, anatomical structures get blurred along the depth direction and produce out-of-plane artifacts. In particular, high-contrast objects are producing strong streak artifacts in the tomosynthesis reconstruction due to the sparse angular sampling.

Here, a second pass method is proposed which is based on a segmentation of the high-contrast structures in a first pass reconstruction by hysteresis thresholding. The segmented structures are then forward projected onto the projection views. Then the measured projections are replaced at these particular positions with interpolated values obtained from a local neighbourhood. The modified projection data are used in a second pass reconstruction to generate an artifact-free volume image. Finally, the segmented high-contrast objects are combined with the artifact corrected reconstruction.

The suggested method has been applied to a series of simulated breast phantom data, which have been generated from segmented MRI data.

7961-45, Session 9

3D task-based performance assessment metrics for optimization of performance and dose in breast tomosynthesis

S. Richard, E. Samei, Duke Univ. (United States)

This study aimed to investigate a method for empirically evaluating 3D imaging task performance of breast tomosynthesis imaging systems. A simulation and experimental approach was used to develop a robust method for performance assessment. To identify a method for experimentally assessing the 3D modulation transfer function (MTF), a breast tomosysnthesis system was first simulated using cascaded system analysis to model the signal and noise characteristics of the projections. A range of spheres with varying contrast and size were reconstructed using filtered back projection from which the 3D MTF was evaluated. Results revealed that smaller spheres result in lower artifacts in the measured MTF, where a sphere of 0.5 mm was found ideal for experimental purposes. A clinical tomosynthesis unit was used as a platform for quantifying the effect of acquisition and processing parameters (e.g., angular extent and sampling, kVp, dose, and voxel size) on breast imaging performance. The 3D noise-power spectrum (NPS) was measured using a uniform phantom and MTF was measured using 0.5 mm ruby spheres. These metrics were combined with a mathematical description of imaging task to generate a figure of merit called the detectability index for system evaluation and optimization. Clinically relevant imaging tasks were considered, such as the detection and localization of a spherical mass. The detectability index was found to provide a useful metric that accounts for the complex 3D imaging characteristics of breast tomosynthesis. Results highlighted the dependence of optimal technique on the imaging task. They further provided initial validation of an empirically assessed figure of merit for clinical performance assessment and optimization of breast tomosynthesis systems.

7961-46, Session 9

Dose and diagnostic image quality in digital tomosynthesis imaging of facial bones in pediatrics

J. King, CancerCare Manitoba (Canada); S. Hickling, The Univ. of Western Ontario (Canada) and CancerCare Manitoba (Canada); I. A. Elbakri, CancerCare Manitoba (Canada) and Univ. of Manitoba (Canada); M. H. Reed, J. Wrogemann, The Children's Hospital of Winnipeg (Canada)

The purpose of this study was to evaluate the use of digital tomosynthesis (DT) for pediatric facial bone imaging. We compared the eye lens dose and diagnostic image quality of DT facial bone exams relative to digital radiography (DR) and computed tomography (CT), and investigated whether we could modify our current DT imaging protocol to reduce patient dose while maintaining sufficient diagnostic image quality. We measured the dose to the eye lens for all three modalities using high-sensitivity thermoluminescent dosimeters (TLDs) and an anthropomorphic skull phantom. To assess the diagnostic image quality of DT compared to the corresponding DR and CT images, we performed an observer study where the visibility of anatomical structures in the DT phantom images were rated on a four-point scale. We then acquired DT images at lower doses and had radiologists indicate whether the visibility of each structure was adequate for diagnostic purposes. For typical facial bone exams, we measured eye lens doses of 0.2-0.4 mGy for DR, 0.3-3.7 mGy for DT, and 26 mGy for CT. In general, facial bone structures were visualized better with DT then DR, and the majority of structures were visualized well enough to avoid the need for CT. DT imaging provides high quality diagnostic images of the facial bones while delivering significantly lower doses to the lens of the eye compared to CT. In addition, we found that by adjusting the imaging parameters, the DT effective dose can be reduced by up to 50% while maintaining sufficient image quality.

7961-47, Session 9

A 3D linear system model for the optimization of dual energy contrast enhanced digital breast tomosynthesis

Y. Hu, W. Zhao, Stony Brook Univ. (United States)

Digital breast tomosynthesis (DBT) is a three-dimensional (3D) x-ray imaging modality that has been shown to decrease the obscuring effect of breast structural noise, thereby increasing lesion conspicuity. To further improve breast cancer detection, much recent work has been devoted to the development of contrast enhanced DBT (CEDBT). Taking advantage of angiogenesis in malignant tissue, CEDBT involves the injection of radio-opaque material (i.e. iodine) and measures the relative increase in uptake of contrast in breast cancer. Either temporal or dual energy subtraction techniques may be used to implement CEDBT. Our present work is to develop a cascaded linear system model for DBT with a CEDBT option to calculate the ideal observer signal to noise ratio (SNR) of lesions in the presence of structural noise, and evaluate the efficacy of CEDBT in the removal of structural noise and the associated increase in x-ray quantum noise. Our model will include the effects of dual energy subtraction on signal and noise transfer, and transfer of power-law form anatomical noise through a DBT system using a modified filtered backprojection (FBP) algorithm. This model will be used for the optimization of x-ray techniques and reconstruction filters in CEDBT.

7961-48, Session 9

Effects of image lag and scatter for dual-energy contrast-enhanced digital breast tomosynthesis using a CsI flat-panel based system

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Dual-energy contrast-enhanced digital breast tomosynthesis (CE-DBT) using an iodinated contrast agent is an imaging technique providing 3D functional images of breast cancer vascularity and tissue perfusion. The iodine uptake in the breast is very small and causes only small changes in x-ray transmission; typically less than 5%. This presents significant technical challenges on the detector and system performance. The purpose of this paper was to characterize image lag and scattered radiation and their effects on image quality for dual-energy CE-DBT using a CsI(Tl) phosphor-based detector. Lag was tested using typical clinical acquisition sequences and exposure parameters and under various detector read-out modes. The potential benefit of an anti-scatter grid on the magnitude and range of the cupping artifact and the ability to cancel breast texture were investigated. Analyses were performed through phantom experiments. Our results illustrate that the magnitude of image lag is negligible and breast texture cancelation is almost perfect when the detector is read out several times between x-ray exposures. An anti-scatter grid significantly reduces the cupping artifact and improves breast texture cancelation.

7961-49, Session 9

Investigation of the effect of tube motion in breast tomosynthesis: Continuous or step and shoot?

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Digital breast tomosynthesis (DBT) is a 3D modality that has the potential to complement or replace 2D digital mammography. One major design aspect of DBT systems is the choice of tube motion; continuous tube motion during x-ray exposure or the step and shoot method where

the tube is held fixed while the x-rays are released. Systems with continuous tube motion suffer from focal spot motion blurring but reduced patient motion blurring due to potentially faster acquisition times compared to step and shoot for the full DBT acquisition. In order to examine the influence of focus motion on lesion detectability, a simulation environment was developed where lesions such as microcalcifications and masses are inserted into different thicknesses of simulated breast volumes. A version of the power law noise method was employed to approximate realistic anatomical breast volumes. The simulated projection images were reconstructed and appropriate metrics (contrast and signal-difference-to-noise ratio) of the lesions in the two different modes were compared. Preliminary results demonstrated the superiority of the step and shoot method over the continuous mode for microcalcifications. However, the results are to be extended to cover a greater number of lesions and breast thicknesses.

7961-50, Session 9

Real-time scanning beam digital x-ray image guidance system for transbronchial needle biopsy

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We investigate a real-time digital tomosynthesis (DTS) imaging modality, based on the scanning beam digital x-ray (SBDX) hardware, used in conjunction with an electromagnetic navigation bronchoscopy (ENB) system to provide improved image guidance for minimally invasive transbronchial needle biopsy (TBNbx). Because the SBDX system source uses electron beams, steered by electromagnets, to generate x-rays, and the ENB system generates an electromagnetic field to localize and track locatable guides, the two systems will affect each other when operated in proximity. We first investigate the compatibility of the systems by measuring the ENB system localization error as a function of distance between the two systems. The SBDX system reconstructs DTS images, which provide depth information, and so we investigate the improvement in lung nodule visualization using SBDX system DTS images and compare them to state-of-the-art fluoroscopic images currently used for biopsy verification. Target localization error remains below 2mm (or virtually error free) if the volume-of-interest (VOI) is at least 50cm away from the SBDX system source and detector. Inside this region, tomographic angle ranges from 3 to 10 degrees depending on the VOI location. Improved lung nodule (<=20mm diameter) contrast is achieved by imaging the VOI near the SBDX system detector, where the tomographic angle is maximized. The combination of the SBDX image guidance with an ENB system would provide real-time visualization during biopsy with improved localization of the target and needle/biopsy instrument, thereby increasing the average and lowering the variance of the yield for TBNbx.

7961-51, Session 10

Towards differential x-ray phase contrast imaging on a compact setup

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Recent developments in X-ray phase contrast imaging showed that a grating interferometer can be used to extract high resolution absorption, phase and dark-field signals simultaneously. In particular, exploiting phase contrast leads to a significant contrast enhancement (e.g. in biological soft tissue) compared to absorption based X-ray imaging [1,2].

Recently, a setup has been demonstrated, which allows differential phase contrast (DPC) imaging on conventional X-ray tubes [3], although the source to detector length of this setup was well above 1m.

Here we present a new setup for DPC imaging with very short source to detector distances (<50cm), i.e. in cone-beam configurations typical of commercially available, absorption-based microCT equipment. Although using a low power microfocus tube, the short setup allows maintaining short exposure times.

Going towards a compact setup leads to two major limiting factors, beam coherence and divergence. Even for microfocus sources, the width of the source becomes critical due to the short source-detector distance. In this contribution, we report on solving this problem by optimizing the setup parameters (i.e. grating positions and periods).

The extreme beam divergence and the high aspect ratio (AR) of the grating structures lead to a reduction of the field of view (FOV). If the X-rays penetrate the gratings with an angle close to or larger than 1/AR, the DPC signal decays rapidly. A solution to this problem is the fabrication of bent gratings with a cylindrical shape. Here, we report on the progress of the fabrication process of such gratings and present first imaging results.

References

[1] F. Pfeiffer et al., Phys. Med. Biol., 52 (6923-6930), 2007

[2] S.A. McDonald et al., J. Synchrotron Rad., 16 (562-572), 2009

[3] F. Pfeiffer et al., Nature Phys., 2 (258-261), 2006

7961-52, Session 10

Beam hardening in x-ray differential phase contrast computed tomography

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The effects of beam hardening have been an issue from the beginning of x-ray computed tomography. Polyenergetic beams are attenuated more at lower energies, resulting in the so-called hardening of the beam. Beam hardening artifacts in diagnostic images are a result of the attenuation coefficient being a non-linear combination of photoelectric and Compton components. In theory, in phase contrast imaging, the fundamental imaging equation shows a single dependence on energy, which would mitigate the presence of beam hardening effects for most imaging tasks. In this work, we use grating based differential phase contrast imaging, which uses a polyenergetic source, and extracts phase information from a set of intensity images. The energy dependence in the imaging equation for differential phase contrast imaging, coupled with the beam hardening present in the measured intensity data, results in beam hardening artifacts in the reconstructed results. We demonstrate the magnitude of the beam hardening effects in phase contrast reconstructions and compare it to standard absorption reconstructions.

7961-53, Session 10

Field of view doubling in differential phase contrast computed tomography

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X-ray phase contrast imaging has been a widely investigated area of research in recent years. Although clinical and industrial applications have been proposed, many of the demonstrated techniques have been applied only to small image objects. One such technique, which has shown great promise for future applications, is the Talbot-Lau x-ray interferometer. One of the factors which currently limits the field of view

in this particular method is the size of the x-ray gratings used in the interferometer. Given the planar grating geometry, pushing to larger fields of view by using larger gratings results in signal degradation due to the divergent nature of the x-ray beam. In this work, a recently developed reconstruction algorithm is used to double the field of view for a given grating size compared to conventional reconstruction techniques. The utility of the method is demonstrated with reconstructions of objects up to 11 cm in diameter using gratings that would conventionally only support a 5.5 cm field of view. This method would be an important enabling technology for the practical use of phase contrast CT in applications such as breast imaging.

7961-54, Session 10

Spectroscopic measurements concerning grating-based x-ray phase-contrast imaging

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We present the first energy-dependent measurement results, regarding grating-based X-ray phase-contrast imag- ing. These were done using a Talbot-Lau grating interferometer according to the proposal made by Weitkamp et al. [1] with the source being a commercial microfocus X-ray tube producing a standard tungsten spectrum. The spectroscopic, pixelated, photon-counting Timepix detector [2] was used for photon detection. Using this set-up, we measured the visibilities for different energies at multiple source to phase-grating distances. These results showed a constant maximum visibility, shifting to higher energies increasing the distance. This behaviour can be explained by changing the distance leads to a change in the set-up's effective design energy. The results also showed that this effect, causing severe problems at monoenergetic X-ray sources as provided at synchrotron beam lines, can be neglected, when using a polychromatic X-ray source. This knowledge about the energy-dependency of the set-up's parameters will help to optimise them towards the clinical application of X-ray phase-contrast imaging. Therefore, further research is scheduled to be done on this topic in the near future, like deconvolving the measurements to delete the detectors influence on the results. In addition, simulations are going to be done using our in-house developed simulation tool [3,4].

7961-55, Session 10

3D diffraction tomography for visualization of contrast media

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In x-ray CT the ability to selectively isolate a contrast agent signal from the surrounding soft tissue and bone can greatly enhance contrast visibility and enable quantification of contrast concentration. We present here a 3D diffraction tomography implementation which allows us to selectively retain volumetric diffraction signal from contrast agent particles that are within a banded size range while eliminating the background signal from soft tissue and bone. For this purpose, we developed a CT implementation of a single-shot x-ray diffraction imaging technique which employs two spaced orthogonal gratings to achieve the selectivity. This technique yields both diffraction and absorption images from a single grating-modulated projection image through analysis in the spatial frequency domain. For this study, a solution of iron oxide nano-particles, which have very different x-ray diffraction properties from tissue, was injected into chicken wings and sections of such wings were then imaged in a 3D diffraction CT setup by acquiring projections at several angular positions. Parallel beam reconstruction was used to combine information from these projections to develop the volumetric dataset of both absorption and diffraction. While the soft tissue, bone and contrast media are observed in the absorption volume reconstruction, only the contrast media is observed in the diffraction volume reconstruction. This 3D diffraction tomographic reconstruction permits the visualization and quantification of the contrast agent isolated from the soft tissue and bone visualization.

7961-56, Session 11

Penalized-likelihood reconstruction for sparse data acquisitions with unregistered prior images and compressed sensing penalties

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This paper introduces a general reconstruction technique for using unregistered prior images within model-based penalized-likelihood reconstruction. The resulting estimator is implicitly defined as the maximizer of an objective composed of a likelihood term that enforces a fit to data measurements and that incorporates the heteroscedastic statistics of the tomographic problem; and a penalty term that penalizes differences from prior image. Compressed sensing (p-norm) penalties are used to allow for differences between the reconstruction and the prior. Moreover, the penalty is parameterized with registration terms that are jointly optimized as part of the reconstruction to allow for mismatched images. We apply this novel approach to synthetic data using a digital phantom as well as tomographic data derived from a cone-beam CT test bench. The test bench data includes sparse data acquisitions of a custom modifiable anthropomorphic lung phantom that can simulate lung nodule surveillance and lung biopsy procedures. Sparse reconstructions using this approach demonstrate the simultaneous incorporation of prior imagery and the necessary registration to utilize those priors.

7961-57, Session 11

Quantification of temporal resolution and its reliability in the context of TRI-PICCS and dual source CT

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Temporal resolution is an important issue especially in cardiac CT. To quantify it, often merely the time that is needed to acquire rawdata that contribute to a reconstructed image is used. In combination with more complex reconstruction algorithms, which aim to improve the temporal resolution, (e.g. TRI-PICCS) this procedure has proven to be inadequate. This study proposes and evaluates a more accurate simulation-based technique to assess the temporal resolution of a CT system (including its reconstruction algorithm). To calculate the temporal resolution of the system on a single point within the field of measurement, a vessel which performs a cardiac motion pattern is simulated at this position. The motion pattern is adapted such that the contrast loss caused by motion exactly meets a defined threshold and then the temporal resolution can be taken from that motion pattern. Additionally the dependency of the temporal resolution on the direction of the motion is evaluated to obtain a measure of the reliability. The method is applied on single source and dual source full scan and short scan reconstructions as well as on a TRI--PICCS reconstruction. The results give an accurate impression on the system response to motion. In conclusion, the proposed method allows showing maps of the temporal resolution and the reliability of a CT system as a function of the position in the field of measurement and in dependency of the source positions.

7961-58, Session 11

Evaluation of a novel CT image reconstruction algorithm with enhanced temporal resolution

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We present an evaluation of a novel algorithm that is designed to enhance temporal resolution in CT beyond the short-scan limit by making use of a histogram constraint.

A minimum scan angle of 180° plus fan angle is needed to acquire complete data for reconstructing an image. Conventionally, this means that a temporal resolution of half the gantry rotation time is achievable in the isocenter and that an enhancement of temporal resolution can only be accomplished by a faster gantry rotation or by using a dual-source system. In this work we pursue a different approach, namely employing an iterative algorithm to reconstruct images from less than 180° of projections and using a histogram constraint to prevent the occurrence of limited-angle artifacts. The method is fundamentally different from previously published approaches using prior images and TV minimization. Furthermore, motion detection is used to enhance dose usage in those parts of the image where temporal resolution is not critical. We evaluate the technique with patient and phantom scans as well as using simulated data.

The proposed method yields good results and image quality, both with simulated and with clinical data. Our evaluations show that an enhancement of temporal resolution to a value equivalent to about 120° of projections is viable, which corresponds to an enhancement of temporal resolution by about 30%. Furthermore, by employing motion detection, a substantial noise reduction can be achieved in those parts of the image where no motion occurs.

7961-59, Session 11

A Compton imaging algorithm for on-line monitoring in hadron therapy

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Hadron therapy, a subject of study by the ENVISION project, promises to provide enhanced accuracy in the treatment of cancer. The Bragg-peak, characteristic of the hadron-beam structure provides larger dose to the tumor while being able to spare surrounding tissue - even tissues in the beam-path, beyond the tumor-site. However, increased dose gradients require accurate treatment, as small beam misalignment can result in dose to healthy, often delicate, surrounding tissue. The requirement for accuracy necessitates imaging during therapy, yet the lack of a transmitted beam makes this difficult. The particulate beam interacts with the target material producing neutrons, positron emitting isotopes and a broad spectra of gamma radiation. Photons from positron-annihilation allow in-beam PET to provide on-line measurements of dose deposition during therapy. However, ib-PET suffers from low statistics and lost projections due to low sensitivity and detector constraints respectively. Instead, Compton imaging is proposed to provide on-line monitoring for hadron therapy. Compton imaging suffers similarly from low statistics, especially, as is the case here, when incident energy is unknown. To surmount this problem, a method of Compton image reconstruction is proposed and tested using simulated data, which reconstructs incident energy along with the spatial variation in emission density. Through incident energy estimation, a larger range of measurements are available for image-reconstruction - greatly increasing the sensitivity of the system. It is shown in this preliminary study that, even with few statistics, a reasonable estimate of the beam path is calculable.

7961-60, Session 11

Method for reducing windmill artifacts in multislice CT images

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Images reconstructed from helical multi-slice CT scans typically display artifacts known as “windmill” artifacts, which arise from not satisfying the Nyquist sampling criteria in the patient longitudinal direction. Since these are essentially aliasing artifacts, they can be reduced or removed by trading off resolution, either globally (by reconstructing a thicker slice thickness) or locally (by local smoothing of the strong gradients). The obvious drawback to this approach is the associated loss in resolution. Another approach is to utilize an x-ray tube with the capability to modulate the focal spot in the z-direction, to effectively improve the sampling rate.

This work presents a new method for windmill artifact reduction based on total variation minimization in the image domain, which is capable of removing the windmill artifacts while at the same time preserving the resolution of the anatomic structures in the images. This is a big improvement over previous reconstruction methods which sacrifice resolution, and provides nearly the same benefits as a z-switching x-ray tube with a much simpler impact to the overall CT system.

7961-61, Session 11

Helical x-ray differential phase contrast computed tomography

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Helical computed tomography revolutionized the field of x-ray computed tomography two decades ago. The simultaneous translation of an image object with a standard computed tomography acquisition allows for faster scanning times for longer image objects when compared with a step-and-shoot method. X-ray phase sensitive imaging methods have typically been limited to smaller fields of view due to the difficulty in constructing the imaging systems and the fact that many are limited to a laboratory environment. One implementation of phase contrast imaging, a Talbot-Lau grating interferometer, has recently demonstrated its potential for implementation in clinical and industrial applications. In this work, the principles of helical computed tomography are extended to differential phase contrast imaging to produce volumetric reconstructions based on fan-beam data. The results are compared with cone beam data to show their equivalence. The method demonstrates the potential for helical reconstructions to be used to scan long objects both faster and with a smaller cone angle.

7961-62, Session 12

Synthetic CT: simulating arbitrary low dose single and dual energy protocols

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While imaging protocol is a critical determinant of radiation dose and image quality, it is difficult to find the protocol (kVp, mAs, filtration) that offers the lowest dose for images of appropriate diagnostic quality. Therefore, we developed a method for retrospectively synthesizing CT scans of arbitrary kVp and filtration for single and dual energy protocols using a previously acquired dual energy scan.

Axial scans of a phantom were acquired on a GE CT750 HD system at 80 kVp and separately at 140 kVp. Additional scans at 100 and 120 kVp and at different exposures were made to compare with synthesized results. Material decomposition is performed in projection space, and the desired spectrum is transmitted through the material decomposition. However, to synthesize realistic single energy scans and dual energy decompositions, the noise must have the correct statistics. The original

data has an inherent noise that can be found from the covariance of the decomposition. Noise is then added so that the total noise matches the expected noise of the simulated protocol.

The resulting synthesized 100 kVp scans are indistinguishable from the actual 100 kVp scans. Similarly, a synthesized 100/120 kVp dual energy decomposition is equivalent to the actual decomposition. In conclusion, synthetic CT enables users to see the impact of protocol changes on the contrast and noise of single and dual energy scans by providing realistic feedback that can be used to develop lower dose protocols for future scans by demonstrating dose/noise/protocol trade-offs and source filtration effects.

7961-63, Session 12

A tabletop clinical x-ray CT scanner with energy-resolving photon counting detectors

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Photon counting detectors (PCDs) are an emerging technology in x-ray computed tomography (CT) as they have the potential to overcome some of the most significant limitations of current CT with energy integrating detectors. Among these are: insufficient tissue contrast, relatively high radiation dose, tissue non-specificity, and the non-quantitative nature. In contrast, CT with PCDs has shown promise in producing higher contrast, tissue specific, quantitative images at lower dose. Novel applications for PCDs include k-edge and functional imaging and material decomposition. A limiting factor, however, is the high photon flux that occurs in clinical applications resulting in signal pulse pile up in the detector. Faster detectors and new strategies for data corrections and image reconstruction algorithms are needed to overcome these limitations. A research tabletop x-ray CT scanner was developed with the following aims: 1) to characterize and calibrate the PCD; 2) to acquire CT projection data under conditions similar to those of clinical CT; and 3) to complement computer simulations by evaluating detector models with pulse pileup and energy-resolved image reconstruction algorithms in a realistic test environment. The scanner employs a commercial clinical x-ray tube, a PCD with two energy thresholds, and allows to scan objects of up to 50 cm in diameter. This paper presents measurements of detector quantities crucial for data corrections and calibration, such as energy response, deadtime, and count rates. Finally, CT images will be presented that were reconstructed using a recently developed detector model and reconstruction algorithm for PCDs.

7961-64, Session 12

Investigating possible improvements in image quality with energy weighting photon counting breast CT

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In an effort to improve the early stage detection and diagnosis of breast cancer, a number of research groups have been investigating the use of x-ray computerized tomography (CT) systems dedicated for use in imaging the breast. Preliminary results suggest that dedicated breast CT systems can provide improved visualization of 3D breast tissue as compared to conventional mammography. However, current breast CT prototypes that are being investigated have limitations resulting in less than desirable spatial resolution, lesion contrast, and signal-to-noise (SNR) ratio. For a number of reasons, the performance of energy integrating detectors are sub-optimal for use in CT imaging of the breast. It is expected that the next generation of x-ray detectors for digital radiography and CT will have the capability of counting individually measured photons and recording their energy. Since the number of optical photons produced when an x-ray interacts within a scintillator is proportional to the energy of the x-ray, integrating energy detectors inherently weight each x-ray according to its energy. Thus, integrating energy detectors inherently weight x-rays contrary to their information content. In this paper, we used computer simulations to evaluate improvements in image quality that can be attained using energy weighting photon counting detectors for breast CT and lower (40-60) kVp settings. Results from this study suggest that improvements in SNR performance can be attained with photon counting detectors as compared to energy integrating detectors. It was also observed that energy weighting can provide 19.9 - 27.4% increase in SNR performance as compared to no energy weighting.

7961-65, Session 12

Temporal and spectral reconstruction algorithms for x-ray CT

S. M. Johnston, C. T. Badea, Duke Univ. (United States)

X-ray CT imaging is a powerful tool for observing dynamic physiological processes, but the hardware and software requirements for performing volumetric reconstructions of these processes are especially demanding. Spectral x-ray CT imaging is one technique with the potential to improve the quality of reconstruction and provide enhanced material contrast. Both temporal and spectral CT have motivated the development of dedicated reconstruction algorithms that exploit the known properties of the temporal and spectral phenomena present in living animals. We present a set of algorithms that can be applied to both the temporal and spectral dimensions, as well as their combination. These algorithms are based on existing spectral reconstruction algorithms, and are derived from a mathematical model of the x-ray acquisition process that represents temporal and spectral information in an identical form. This model enables us to calculate the gradients of two measures of reconstruction quality, and each formulation of the gradient leads to two algorithms for optimizing the reconstruction in terms of the quality measure. We implement these algorithms using a software architecture that is accelerated with a graphics processing unit (GPU), and we apply this implementation to a scan of a simulated phantom. Further results from an in vivo small animal CT study will be presented at the meeting.

7961-66, Session 12

Material separation in x-ray CT with energy resolved photon-counting detectors

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The objective of the study was to demonstrate that more than two types of materials can be effectively separated with x-ray CT using a recently developed energy resolved photon-counting detector. We performed simulations and physical experiments using an energy resolved photon-counting detector with six energy thresholds. For comparison, dual-kVp CT with an integrating detector was also simulated. Iodine- and gadolinium-based contrast agents, as well as several soft-tissue- and bone-like materials were imaged. We plotted the attenuation coefficients for the various materials in a scatter plot for pairs of energy windows. In both simulations and physical experiments, the contrast agents were easily separable from other non-contrast-agent materials in the scatter plot between two properly chosen energy windows. This separation was due to discontinuities in the attenuation coefficient around their unique K-edges. The availability of more than two energy thresholds in a photon-counting detector allowed the separation with one or more contrast agents present. Compared with dual-kVp methods, CT with an energy resolved photon-counting detector provided a larger separation and the freedom to use different energy window pairs to specify the desired target material.

We concluded that an energy resolved photon-counting detector with more than two thresholds allowed the separation of more than two types of materials, e.g., soft-tissue-like, bone-like, and one or more materials with K-edges in the energy range of interest. They provided advantages over dual-kVp CT in terms of the degree of separation and the number of materials that can be separated simultaneously.

7961-67, Session 13

An inverse geometry CT system with stationary source arrays

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

Traditional CT systems face a tradeoff between temporal resolution, volumetric coverage and cone beam artifacts and also have limited ability to customize the distribution of incident x-rays to the imaging task. Inverse geometry CT (IGCT) can overcome these limitations by placing a small detector opposite a large, rotating scanned source array. The minimum rotation time of IGCT may be limited by challenges related to rotating a large source array. By replacing this rotating source with one or more stationary scanned sources we can greatly accelerate gantry rotation speeds and hence temporal resolution. The feasibility of using IGCT with stationary scanned sources is investigated. We anticipate that it will be necessary to have physical separation between source arrays, creating gaps in the sinogram. Symmetry can be used to fill in all the missing rays except those connecting gaps. With three source arrays, a large triangular field of view emerges. As the small detector orbits the patient each source spot must be energized at multiple specifically designed times to ensure adequate sampling. A timing scheme is proposed that avoids timing clashes, efficiently uses the detector, and allows for simple collimation. The two-dimensional MTF and noise characteristics are found to be comparable to parallel-beam systems. A two-dimensional Shepp-Logan phantom is also simulated, and the artifact levels are comparable to a parallel-beam scan. A complete, 100 millisecond volumetric scan may be feasible.

7961-68, Session 13

Dual energy micro-CT imaging for differentiation of iodine and gold-based nanoparticles

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Molecular imaging strategies include the use of multiple imaging probes with different specificity. We investigate how dual energy micro-CT can discriminate between probes containing iodine (I) and gold (Au) simultaneously present in the body. Phantom experiments were performed to measure the CT enhancement for I and Au over a range of voltages from 40-to-150 kVp using a dual source micro-CT system. The two voltages that provide maximum CT enhancement for Au and I without filtration were determined to be 40 kVp and 80 kVp. Next, an in vivo longitudinal animal study was performed with iodinated liposomes (Lip-I) and gold nanoparticles (AuNP). A mouse was first injected with 0.3 ml Lip-I. Three days later, the same animal was scanned with respiratory-gated dual energy micro-CT at 40 kVp and 80 kVp. Next, the animal was injected with 0.15 ml AuNP (AuroVistTM) and re-scanned. The dual energy sets were used to estimate the concentrations of Au and I via a simple two-material decomposition method. The results indicate that, for the same concentrations, the relative average enhancement of Au to I was 2.83 at 40 kVp and 1.58 at 80 kVp. The concentration maps confirmed the expected biodistribution with only I uptake in the liver and spleen, and both I and Au present in the blood pool. In conclusion, dual energy micro-CT can be used to discriminate probes containing I and Au. The sensitivity limits of this method are being explored and further results will be presented at the meeting.

7961-69, Session 13

Design and development of MR-Compatible SPECT systems for simultaneous SPECT-MR imaging of small animals

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We describe a continuing design and development of MR-compatible SPECT systems for simultaneous SPECT-MR imaging of small animals. A first generation prototype SPECT system was designed and constructed to fit inside a MRI system with a gradient bore inner diameter of 12 cm. It consists of 3 angularly offset rings of 8 detectors (1”x1”, 16x16 pixels MR-compatible CZT). A matching 24-pinhole collimator sleeve, made of a tungsten-compound, provides projections from a common FOV of ~25 mm. A birdcage RF coil for MRI data acquisition surrounds the collimator. The SPECT system was tested inside a clinical 3T MRI system and minimal interference was observed on the simultaneously acquired SPECT and MR images. We developed a sparse-view image reconstruction method based on accurate modeling of the point response function of each of the 24 pinholes to provide artifact-free SPECT images. The stationary SPECT system provides relatively low resolution of 3-5 mm but high geometric efficiency of 0.5-1.2% for fast dynamic acquisition, demonstrated in a SPECT renal kinetics study using Tc-99m DTPA. Based on these results, a second generation prototype MR-compatible SPECT system with an outer diameter of 20 cm that fits inside a mid-sized preclinical MRI system is being developed. It consists of 5 rings of 19 CZT detectors. The larger ring diameter allows the use of different multi-pinhole collimator designs, high system resolution up to ~1 mm, high geometric efficiency, or lower system resolution without collimator rotation. The anticipated performance of the new system is supported by simulation data.

7961-70, Session 13

Freehand SPECT in low uptake situations

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3D functional imaging in the operating room can be extremely useful for some procedures like SLN mapping or SLN biopsies. Freehand SPECT is an example of such an imaging modality, combining manually scanned, hand-held 1D gamma detectors with spatial positioning systems in order to reconstruct localized 3D SPECT images, for example in the breast or neck region. Standard series expansion methods are applied together with custom physical models of the acquisition process and custom filtering procedures to perform 3D tomographic reconstruction from sparse, limited-angle and irregularly sampled data. A Freehand SPECT system can easily be assembled on a mobile cart suitable for use in the operating room. This work addresses in particular the problem of objects with low uptake (like sentinel lymph nodes), where reconstruction tends to be difficult due to low signal to noise ratio. In a neck-like phantom study, we show that four simulated nodes of 250 microliter volume with 0.06% respectively 0.03% uptake of a virtual 70MBq injection of Tc99m (the typical activity for SLN procedures at our hospital) in a background of water can be reconstructed successfully using careful filtering procedures in the reconstruction pipeline. Ten independent Freehand SPECT scans of the phantom were performed by several different operators, with an average scan duration of 5.1 minutes. The resulting reconstructions show an average spatial accuracy within voxel dimensions (2.5mm) compared to CT and exhibit correct relative quantification.

7961-71, Session 13

Forward model of Cerenkov luminescence tomography with the third-order simplified spherical harmonics approximation

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Applying Cerenkov luminescence tomography (CLT) to localizing Cerenkov light sources in situ is still in its nascent stage.

One of the obstacles hindering the development of the CLT is the lack of dedicated imaging mode. In this contribution, the paper presented a Cerenkov optical imaging mode, in which the propagation of optical photons inside tissues generated by the Vavilov-Cerenkov effect is modeled based on simplified spherical harmonics approximation. As a significantly more transport-like and computational-efficient approximation theory, the performance of the third-order simplified spherical harmonics approximation (SP3) in the CLT forward is investigated in stages. Finally, the performance of the proposed forward model is validated using numerical phantoms and compared with the simulation data based on the Monte Carlo method. Photon flux densities of SP model were consistent with that of MC model. Further, the biodistribution of the radiotracer inside the heterogeneous media can be imaged by using the proposed CLT technique without the need of expensive dedicated PET or SPECT.

7961-72, Session 13

A preclinical SPECT camera with depth-of-interaction compensation using a focused-cut scintillator

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Preclinical SPECT offers a powerful means to understand the molecular pathways of metabolic activity in animals. SPECT cameras using pinhole collimators offer high resolution by means of image magnification. One of the limitations of pinhole geometries is that increased magnification causes some rays to travel through the scintillator detector at steep angles, introducing parallax errors due to variable depth-of-interaction in scintillator material, especially towards the edges of the detector field of view. These parallax errors ultimately limit the resolution of pinhole preclinical SPECT systems, especially for higher energy isotopes that can easily penetrate through millimeters of scintillator material. This problem is especially severe in preclinical systems using CCD cameras, as their intrinsic resolution may be in the order of 50 mm, while the parallax errors can be in the order of 1 to 2 mm.

We have built a high resolution, multi-pinhole SPECT camera prototype, using an EMCCD camera coupled to a 3 mm thick CsI(Tl) scintillator whose pillars are focused towards a four 500 mm square knife edge pinhole collimator. The pixellated, focused-cut scintillator, with its pixels laser-cut such that they are collinear with incoming rays, thereby compensating for these parallax errors. The focused cut scintillator was fabricated using a laser ablation process that allows for cuts very high aspect ratios. The limit of the resolution is set by the pixel size of scintillator, and the size of the pinhole and thus expected to give reconstructed image resolution of 500 microns. We present the performance characteristics of this camera as well as phantom image

7961-73, Session 14

Evaluation of an erbium modulator in x-ray scatter correction using primary modulation

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A primary modulator made of erbium is evaluated in X-ray scatter correction using primary modulation. Our early studies have shown that erbium is the optimal modulator material for an X-ray cone-beam computed tomography (CBCT) system operated at 120 kVp, exhibiting minimum beam hardening which otherwise weakens the modulator's ability to separate scatter from primary. In this work, the accuracy of scatter correction is compared for two copper modulators (105 and 210 μm of thickness) and one erbium modulator (25.4 μm of thickness) with the same modulation frequencies. The variations in the effective transmission factors of these three modulators as functions of object filtrations are first measured to show the magnitudes of beam hardening caused by the modulators themselves. Their scatter correction performances are then tested using a Catphan@600 phantom on our tabletop CBCT system. With and without 300 μm of copper in the beam, the measured variations for these three modulators are 4.3%, 7.8%, and 0.9%, respectively. Using the 105- and 210-μm copper modulators, our scatter correction method reduces the average CT number error from 327.3 Hounsfield units (HU) to 19.4 and 20.9 HU in the selected regions of interest, and enhances the contrast-to-noise ratio (CNR) from 10.7 to 16.5 and 15.9, respectively. With the 25.4-μm erbium modulator, the CT number error is markedly reduced to 2.8 HU and the CNR is further increased to 17.4.

7961-74, Session 14

Analysis of vertical and horizontal circular C-arm trajectories

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C-arm angiography systems offer great flexibility in the acquisition of trajectories for computed tomography. Theoretically, these systems are able to scan patients while standing in an upright position. This would allow novel insights into structural changes of human anatomy in weight-bearing position. However, a scan on a horizontal trajectory parallel to the ground floor is required to do so which is not supported by standard C-arm CT acquisition protocols.

In this paper, we compared the standard vertical and horizontal scanning trajectories by analysis of the source positions and source to detector distances during the scan. We employed the PDS2 C-arm calibration phantom to compute the exact scan geometry. Based on the analysis of the projection matrices, we computed the source position in 3D and source to detector distance for each projection. Furthermore, we used the calibrated scan geometries to reconstruct the calibration phantom. Based on this reconstruction in comparison to the ideal phantom geometry we also evaluated the geometric reconstruction error.

As expected, both the vertical and the horizontal scan trajectories exhibit a significant C-arm "wobble". In both kinds of trajectories, the reproducibility over three scans was comparable. We were able to reconstruct the calibration phantom with satisfactory geometric reconstruction accuracy. Hence, we conclude that horizontal C-arm scans are possible and show similar properties as vertical C-arm scans.

7961-75, Session 14

Functional phase-correlated micro-CT imaging of small rodents with low dose

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Functional imaging of an animals thoracic region requires cardiac and respiratory gating. The information on respiratory motion and ECG required for double-gating are extracted from the rawdata and used to select the projections appropriate for a given motion phase. A conventional phase-correlated reconstruction (PC) therefore uses only a small amount of the total projections acquired. Thus the resulting images comprise a high noise level unless acquired with very high dose, and streak artifacts may occur due to the sparse angular sampling. Here, we are aiming at getting high fidelity images even for relatively low dose values. To overcome these issues we implemented an iterative reconstruction method encompassing a five-dimensional (spatial, cardiac-temporal, respiratory-temporal) edge-preserving filter. This new phase-correlated low-dose (LDPC) reconstruction method is evaluated using retrospectively-gated, contrast-enhanced micro CT data of mice. The scans performed comprise 7200 projections within 10 rotations over 5 minutes. A tube voltage of 65 kV was used resulting in an administered dose of about 500 mGy. 20 respiratory phases and 10 cardiac phases are reconstructed. Using LDPC reconstruction the image noise is typically reduced by a factor of about six and artifacts are almost removed. Reducing the number of projections available for reconstruction shows that we can get comparable image quality with only 200 mGy. LDPC enables high fidelity low-dose double-gated imaging of free breathing rodents without compromises in image quality. Compared to PC image noise is significantly reduced with LDPC and the administered dose can be reduced accordingly.

7961-76, Session 14

Scatter correction for cone-beam computed tomography using moving blocker strips

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One well-recognized challenge of cone-beam computed tomography (CBCT) is the presence of scatter contamination within the projection images. Scatter degrades the CBCT image quality by decreasing the contrast, introducing shading artifacts and leading to inaccuracies in the reconstructed CT number. We propose a blocker-based approach to simultaneously estimate scatter signal and reconstruct the complete volume within the field of view (FOV) from a single CBCT scan. A physical strip attenuator (i.e., “blocker”), consists of lead strips, is inserted between the x-ray source and the patient. The blocker moves back and forth along z-axis during the gantry rotation. The two-dimensional (2D) scatter fluence is estimated by interpolating the signal from the blocked regions. A modified Feldkamp-Davis-Kress (FDK) algorithm and an iterative reconstruction based on the constraint optimization are used to reconstruct CBCT images from un-blocked projection data after the scatter signal is subtracted. An experimental study is performed to evaluate the performance of the proposed scatter correction scheme. The scatter-induced shading/cupping artifacts are substantially reduced in CBCT using the proposed strategy. In the experimental study using a CatPhan® 600 phantom, CT number errors in the selected regions of interest are reduced from 256 to less than 20. The proposed method allows us to simultaneously estimate the scatter signal in projection data, reduce the imaging dose and obtain complete volumetric information within the FOV.

7961-77, Session 14

Single-scan scatter correction for cone-beam CT using a stationary beam blocker: theory and preliminary study

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Although cone-beam CT (CBCT) is widely used nowadays, its imaging performance is greatly hindered by the inferior image quality mainly owing to large x-ray scatter signals. Among numerous existing algorithms, measurement-based scatter correction methods efficiently obtain accurate scatter estimation without prior knowledge on the object. However, with a beam blocker in the field to completely attenuate primary, it is generally believed that the acquired data in scatter measurement projections are not complete for an accurate reconstruction. Thus an extra scan or moving the blocker during the scan is typically required. In this paper, we propose a new measurement-based scatter correction algorithm to achieve accurate reconstruction with one single scan and a stationary x-ray beam blocker, two seemingly incompatible features. The blocked areas are distributed over the projection where primary signals are redundant using a new beam blocker with a “crossing finger” shape. Scatter is accurately estimated by interpolation and scatter-corrected CT images are obtained using a modified FDK algorithm. Using Monte Carlo (MC) simulation on the Shepp-Logan phantom, we first optimize the blocker geometry. A complete MC simulation of CBCT is then carried out on a uniform symmetric water phantom to save computation time. With the scatter-to-primary ratio around 1.0, our method reduces the CT number error from 293 HU to 2.9 HU. Compared with other existing algorithms, the proposed approach inherits merits from conventional measurement-based methods with new features of single-scan and a stationary beam blocker, which greatly reduce scan time and patient dose, and simplify the practical implementation.

7961-78, Session 15

Verification of the performance accuracy of a real-time skin-dose tracking system for interventional fluoroscopic procedures

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A tracking system has been developed to provide real-time feedback of skin dose and dose rate during interventional fluoroscopic procedures. The dose tracking system (DTS) calculates the radiation dose rate to the patient’s skin using the exposure technique parameters and exposure geometry obtained from the x-ray imaging system digital network (Toshiba Infinix) and presents the cumulative results in a color mapping on a 3D graphic of the patient. We performed a number of tests to verify the accuracy of the dose representation of this system. These tests included comparison of system-calculated dose-rate values with ionization-chamber (6 cc PTW) measured values with change in kVp, beam filter, field size, source-to-skin distance and beam angulation. To simulate a cardiac catheterization procedure, the ionization chamber was also placed at various positions on a Rando torso phantom and the dose agreement compared for a range of projection angles with the heart at isocenter. To assess the accuracy of the dose distribution representation, Gafchromic film (XR-RV3, ISP) was exposed with the beam at different locations. The DTS and film distributions were compared and excellent visual agreement was obtained within the cm-sized surface elements used for the patient graphic. The dose (rate) values agreed within 10% for the range of variables tested. Correction factors could be applied to obtain even closer agreement since the variable values are known in real-time. The DTS provides skin-dose values and dose mapping with sufficient accuracy for use in monitoring diagnostic and interventional x-ray procedures.

7961-79, Session 15

Energy deposition in the breast during CT scanning: quantification and implications for dose reduction

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Studies suggest that dose to the breast leads to a higher lifetime attributable cancer incidence risk from a CT scan for women compared to men. Numerous methods have been proposed for reducing dose to the breast during CT scanning, including bismuth shielding, tube current modulation, partial-angular scanning, and reduced kVp. These methods differ in how they alter the spectrum and flux across projection angle. This study used Monte Carlo CT simulations of a voxelized female phantom to investigate the energy deposition in the breast as a function of both photon energy and projection angle. The resulting energy deposition matrix was then used to investigate two questions regarding dose reduction to the breast: (1) Which photon energies deposit the most dose in the breast, and (2) How does increased filtration compare to tube current reduction? The results demonstrate that while both low and high energy photons deposit relatively large dose per incident photon, the low-energy photons deposit more energy to the breast for a 120 kVp acquisition. The results also demonstrate that decreasing the tube current for the AP views provides nearly the same dose reduction as an ideal shield (21.8% dose reduction compared to 22.2% reduction for the ideal shield). Overall, understanding the energy deposition in the breast as a function of photon energy and projection angle enables comparisons of dose reduction methods and facilitates further development of optimized dose reduction schemes.

7961-80, Session 15

Uncertainties of organ absorbed doses to patients from 18F-cholin

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A method was developed in the framework of the MADEIRA Project (Minimizing Activity and Dose with Enhanced Image quality by Radiopharmaceutical Administrations) to quantitatively analyze the uncertainties in the organ absorbed doses after administration of 18F-cholin to the patients undergoing nuclear medicine diagnostics. The model structure was developed and the model parameter uncertainties were determined on the basis of the patient organ images as well as blood and urine samples. Model parameter values were sampled and biokinetic modeling calculations using these sampled parameter values were performed. Sensitivity of the model parameters was indicated by coupling the model input and output using regression and partial correlation analysis. The uncertainties of absorbed dose to the patients were calculated by applying the new S-values derived with the ICRP/ICRU adult male reference computational phantom. The possible implication of uncertainty and sensitivity information to the time schedule of image acquisition is discussed.

7961-81, Session 15

The feasibility of universal DLP-to-risk conversion coefficients for body CT protocols

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In body CT examinations, effective dose (ED) is often estimated from dose-length product (DLP) using conversion coefficients derived for protocols that cover the entire chest, abdomen-pelvis, or trunk regions. Similar conversion coefficients, however, do not exist for protocols that cover a single organ or a sub-region of the body, as in multi-phase liver protocol. Our goal is to extend the DLP-to-ED conversion coefficients (k factors) to a wide range of body CT protocols and to derive DLP-to-cancer risk conversion coefficients (q factors). Two computational phantoms with realistic anatomy were used: a reference male phantom (75 kg) and its obese rendition (113 kg). Organ dose was estimated using a validated Monte Carlo program for examinations of 10 distinct body sections, corresponding to a wide range of body protocols. Effective dose and risk index (an index of total cancer risk) were then calculated for four patient ages and were normalized by DLP to obtain k and q factors. For a given age and body habitus, the variations of k and q factors across examinations ranged between 22-31% and 9-11%, respectively. The small variations of the q factor suggested the feasibility of a single q factor universal for many body protocols. Relative to the 75-kg phantom, the k and q factors for the 113-kg phantom decreased by ~20%. The q factor for a given phantom decreased linearly with age. Our derivation of the scanner- and protocol-independent q factors can be extended to other ages and body habitus to enable patient-specific cancer risk estimations.

7961-82, Session 15

X-ray dose reduction by adaptive source equalization and electronic region-of-interest control

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The Scanning-Beam Digital X-ray (SBDX) fluoroscopy system has already demonstrated reduced patient dose owing to its high-DQE photon-counting detector, reduced detected scatter, and the elimination of the anti-scatter grid. Here we show that further dose reduction is possible through its unique flexible illumination platform.

The SBDX system has a small-area detector array and a large-area X-ray source with up to 9,000 individually controlled X-ray focal spots. Each focal spot illuminates a small fraction of the full field of view. To acquire a frame, each focal spot is activated for a fixed number of 1-microsecond periods.

Dose reduction is possible by reducing the number of activations of some of the X-ray focal spots during each frame time. This can be done dynamically to reduce the exposure in areas of low patient attenuation, such as the lung field. This spatially adaptive illumination also reduces the dynamic range in the full image, which is visually pleasing. The dose reduction achieved depends on patient anatomy; reductions of 40% have been measured with chest phantoms.

Dose can also be reduced by the user selecting a region of interest (ROI) where full image quality is to be maintained. Outside the ROI, the number of activations of each X-ray focal spot is reduced and the image gain is correspondingly increased to maintain consistent image brightness. Dose reduction is dependent on the size of the ROI and the desired image quality outside the ROI.

Importantly, these dose reduction methods can be implemented in real time without any moveable parts.

7961-83, Session 15

Effect of contrast magnitude on noise-resolution tradeoffs in x-ray CT imaging: a comparison of penalized alternating minimization and filtered backprojection algorithms

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Purpose: To compare the tradeoff of image noise and spatial resolution in x-ray CT reconstruction between a statistical algorithm, penalized Alternating Minimization (AM), and conventional filtered backprojection (FBP), for a range of contrast magnitudes. Methods: Monoenergetic Poisson-counting CT data were simulated for a water phantom containing circular inserts of varying contrast (7% to 238%). The data was reconstructed with FBP and two parameterizations of AM, each with a range of smoothing strengths to quantify the noise-resolution tradeoff curve. Modulation transfer functions (MTFs) were calculated from oversampled edge-spread functions defined by the circular contrast-insert edges. The integral of the MTF up to 0.5 lp/mm was adopted as a single-parameter measure of local spatial resolution. Results: The noise-resolution tradeoff curve was always more favorable for AM than FBP. The ratio of AM-to-FBP image variances imply penalized AM can reconstruct images using 70% to 10% of the dose FBP would require for comparable noise and resolution. This was strongly dependent upon the AM penalty function parameterization and the insert contrast for which resolution is quantified. However, one of the AM parameterizations was found to suffer from poor low-contrast resolution when matching high-contrast resolution with FBP. Conclusions: The penalized AM algorithm shows the potential to reconstruct images of comparable quality using a fraction of the dose required by FBP. The dependency on contrast magnitude used for resolution matching implies the advantage of AM can be maximized by optimizing the local-neighborhood penalty function to the specific imaging task at hand.

7961-93, Poster Session

Iterative CT reconstruction integrating SART and conjugate gradient

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Iterative CT reconstruction methods have advantages over analytical reconstruction methods because of their robustness to both noise and incomplete projection data, which have great potential for dose reduction in real applications. The SART algorithm, which is one of the well-established iterative reconstruction methods, has been examined extensively, and GPU has been applied to improve their efficiency. Although it has been proved that SART may globally converge, its convergence is very slow, especially after the first several iterations. Hundreds of iterations may be needed for accurate reconstruction. This slow convergence requires heavy data transfer between global memory and texture memory inside GPU. Therefore, the conjugate gradient (CG) method, which converges much faster than SART, may be combined with SART for better performance. Since CG is sensitive to initialization, the reconstruction results from SART after a few iterations may be used as the initialization for CG. Preliminary experimental results on CPU show that this framework works well for synthetic data. Experimental results on large real data, along with the total variation minimization and the GPU implementation, will be provided in the full manuscript.

7961-94, Poster Session

Iterative helical cone-beam CT reconstruction using graphics hardware: a simulation study

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Helical cone-beam CT has become one of the most state-of-the-art research topics in medical imaging in recent years. While analytic methods have been proposed to achieve an exact reconstruction for helical cone-beam CT, these methods may not perform well for variations in the imaging geometry, especially for nonstandard spirals. Iterative methods such as SART are advantageous in this aspect. This paper proposes a simulation study on iterative reconstruction methods for helical cone-beam CT using graphics hardware. Since SART is computationally intense, graphics hardware (GPU) may be utilized to handle the computations and increase the efficiency of SART. Other issues, such as resolution in the moving direction of the spirals, effects of dynamic pitch, and effects of TV regularization, may also be explored using iterative reconstruction methods. Preliminary results of GPU SART reconstruction are presented for traditional cone-beam CT. Its extension to helical cone-beam CT is proposed, whose results will be provided in the full manuscript.

7961-95, Poster Session

Iterative image reconstruction for helical cone-beam x-ray CT using a stored system matrix approach

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We present a stored system matrix (SM) approach for the forward and backward projector implementation in iterative image reconstruction (IIR) for helical cone-beam x-ray CT. Because of the symmetry of a helical source trajectory, it is sufficient to calculate and store the SM entries for one image slice only and for all source positions illuminating it. By a judicious selection of the slice thickness, the SM entries for other slices are copies of those stored values. In implementing an IIR method, the 3D reconstruction volume can be based on a non-Cartesian grid so that no SM interpolation is needed. Different basis functions can be used for the 3D image representation. For the convenience of SM generation, in this work we used the blob-based image representation. Using the proposed method, the memory requirement for reconstruction of the full field-of-view of clinical CT scanners is manageable on current computing platforms. To reduce the SM further, the same storage principle is generalized and applied to a small VOI. The VOI IIR method requires a SM that covers a partial ring region of one image slice, and for all source positions illuminating the ring. The width and the angular range of the ring depend on the size of the VOI. We applied the proposed stored SM based IIR method to both computer simulation and patient data. The computational speed and image quality demonstrated that the proposed method can be a candidate that brings IIR methods closer to clinical practice.

7961-96, Poster Session

Accelerate multidimensional CT scanner simulation with GPU

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CT scanner simulation virtually simulates the projection process of CT without actually scanning. It is very useful to design, evaluate and develop CT systems which are evolving into some directions. However, in order to simulate multi slices, multi energy and other dimensions simultaneously, it becomes time consuming because of large amount of computation. In this paper, we present a solution to this problem with CUDA architecture on GPU. Our solution contains three steps. First, CPU prepares the data that will be used by GPU. Then, GPU kernel is launched to calculate the projection of all rays through the phantom data in parallel. In order to get maximum memory bandwidth, we optimized the data storage by padding 2D arrays to ensure the global memory access coalesced. Finally, post processing is done on CPU. Our experiment environment includes a dual core CPU and a NVIDIA Quadro FX 1800 GPU with CUDA compute capability 1.1. CUDA is a new parallel programming model and instruction set architecture released by NVIDIA, which makes the parallel computation more efficiently and programming more easily than previous GPGPU. We used three kinds of phantom data to test the performance. It is found that our solution gets the same image quality in double precision but gains a speed increase of more than 10 times faster than using CPU only.

7961-97, Poster Session

OpenCL, a viable solution for high-performance medical image reconstruction?

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Reconstruction of 3-D volumetric data from C-arm CT projections is a computationally demanding task.

Hardware optimization is mandatory for interventional image reconstruction.

Manufacturers of medical equipment use a variety of high-performance computing (HPC) platforms, like FPGAs, graphics cards, or multi-core CPUs. A problem of this diversity is that many different frameworks and (vendor-specific) programming languages are used. Furthermore, it is costly to switch the platform, since the code has to be re-written, verified, and optimized.

OpenCL, a new industry standard for HPC promises to enable portable code. Its basic idea is to abstract hardware in a way that allows mapping onto CPUs, GPUs, and other hardware. The code is compiled for the actual target by the device driver. In this work we investigated the suitability of OpenCL as a solution to produce portable code that runs efficiently on different hardware. The problems chosen are back- and forward-projection, the most time-consuming parts of (iterative) reconstruction. We show results on three platforms, a multi-core CPU system and two GPUs, and compare them against manually optimized native implementations.

We found that OpenCL allows to share a common framework in one language across platforms. However, considering differences in the underlying architecture, a hardware-oblivious implementation cannot be expected to deliver maximal performance. By optimizing the OpenCL code for the specific hardware we reached over 90% of native performance for both problems, back- and forward-projection.

7961-98, Poster Session

Improved total variation regularized image reconstruction (iTV) applied to clinical CT data

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Compresssed sensing seems to be very promising for image reconstruction in computed tomography. In the last years it has been shown, that these algorithms are able to handle incomplete data sets quite well. As cost function these algorithms use the l1-norm of the image after it has been transformed by a sparsifying transformation. This yields to an inequality-constrained convex optimization problem.

In this paper we present an improved method to solve this problem. Thereby the two parts of the cost functional are treated separately. The main goal of the algorithm proposed is to converge to the best possible rawdata consistency, while holding the cost function at a low value. This is achieved by transferring both optimization procedures into the rawdata domain, so they can be adapted to each other.

To evaluate the algorithm, we process measured clinical datasets. In detail we focus on the problems of limited view angle tomography and data lost due to metal implants.In all cases the presented method reaches convergence within less than 25 iteration steps. The image artifacts caused by incomplete rawdata are mostly removed without introducing new eects like staircasing.

7961-99, Poster Session

Ring artifact corrections in flat-panel-detector based cone beam CT

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Flat-panel detectors (FPDs) are now widely used in cone beam CT. Unlike traditional CTs made of discrete detectors, FPD based CTs often suffer from strong ring artifacts since FPDs often have DC offset drifts and sensitivity fluctuations that cannot be pre-calibrated before the scan. We propose novel techniques for detection and removal of ring artifacts in the sinogram domain. Rather than removing ring artifacts using post processing techniques, we remove ring-artifact-inducing stripe artifacts in the sinogram. Ring artifacts in CT images are caused by abnormal stripes, mostly single but sometimes contiguous multiple stripes, in the sinogram. We propose efficient techniques to detect very weak stripes that have little contrast against the normal background in the sinogram. The weak stripes in the sinogram, even invisible ones, could make conspicuous ring artifacts when the stripes are located in the middle region of the sinogram. We detect the isolated stripes by comparing a measure of the second derivative with a dynamic threshold computed from the first derivative of the sinogram. We detect the contiguous stripes, which create band rings, using the mean curve and multilevel polyphase decomposition of the isolated stripe corrected sinogram. For the correction of ring artifacts, we use variable window moving average (VWMA) and weighted moving average (WMA) filters. We applied the proposed techniques to various types of micro-CT images to evaluate the techniques. Experimental results show that the proposed method can remove ring artifacts effectively without imparting noticeable distortion in the image.

7961-100, Poster Session

Backprojection-filtration image reconstruction from partial cone-beam data for scatter correction

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In this work, we proposed a novel scatter correction method for a circular cone-beam computed tomography (CBCT) using a hardware-based approach that completes both data acquisition and scatter correction in a single rotation. We utilized (quasi-)redundancy in the circular cone-beam data, and applied the chord-based backprojection-filtration (BPF) algorithm to avoid the problem of filtering discontinuous data that would occur if conventional filtered-backprojection (FBP) algorithms were used. A single scan was performed on a cylindrical uniform phantom with beam-block strips between the source and the phantom, and the scatter was estimated for each projection from the data under the blocked regions. The beam-block strips (BBSs) were aligned parallel to the rotation axis, and the spacing between the strips was determined so that the data within the spaces constitute at least slightly more than the minimum data required for image reconstruction. The results showed that the image error due to scatter (about 30 % of the attenuation coefficient value) has been successfully corrected by the proposed algorithm.

7961-101, Poster Session

Fast 4D cone-beam CT reconstruction using the McKinnon-Bates algorithm with truncation correction and nonlinear filtering

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A challenge in using on-board cone beam computed tomography (CBCT) to image lung tumor motion prior to radiation therapy treatment is acquiring and reconstructing high quality 4D images in a sufficiently short time for practical use. For the 1 minute rotation times typical of C-Arm Linacs, severe view aliasing artifacts, including streaks, are created if a conventional phase-correlated FDK reconstruction is performed. The quasi-iterative McKinnon-Bates (MKB) algorithm provides an efficient means of reducing some streaks from static tissue but can produce images with low SNR and other artifacts. To address these weaknesses, we have added truncation correction and adaptive nonlinear filtering to the MKB algorithm to reduce streaking and improve image quality. The modified MKB algorithm was implemented on a graphical processing unit (GPU) to maximize efficiency. Results show that a nearly 4x improvement in SNR is obtained compared to the conventional FDK phase-correlated reconstruction, and that high quality 4D images with 0.4 second temporal resolution and 1 mm3 isotropic spatial resolution can be reconstructed in less than 20 seconds after data acquisition completes.

7961-102, Poster Session

An FBP-type analytic segmentation method for X-ray CT images from cone-beam projection data

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In many medical and non-medical applications, the reconstructed X-ray CT images are subjected to automated pattern recognition algorithms that require segmentation of the images. A typical data processing chain includes image reconstruction, followed by a segmentation step and pattern analysis. In this paper, we introduce a FBP-type image segmentation method applied to cone-beam projection data that bypasses the image reconstruction step. Our method first parameterizes the cone-beam transform with an arbitrary source trajectory and detector plane orientation so that the resulting transform is a Fourier Integral Operator (FIO). We next present a filtered-back projection (FBP) type method to recover and enhance the visible singularities (edges) of the object to be imaged. The FBP-type segmentation involves a back-projection step that is given by the L2-adjoint of the FIO and a filtering step. We design the filter so that the resulting point spread function of the FBP operator is a differential operator behaving in a desirable manner for each pixel reconstructed. While we focus primarily on segmentation of X-ray CT images from cone-beam projections, the method is applicable to other type of applications where the projection data are modeled as FIOs, such as synthetic aperture radar, sonar and geophysical imaging.

7961-103, Poster Session

A contrast adaptive total p-norm variation minimization approach to CT reconstruction for artifact reduction of reduced view perfusion CT imaging

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Perfusion CT (PCT) examinations are getting more frequently used for diagnosis of acute brain diseases such as hemorrhage and infarction, because the functional map images it produces such as regional cerebral blood flow (rCBF), regional cerebral blood volume (rCBV), and mean transit time (MTT) may provide critical information in the emergency work-up of patient care. However, a typical PCT scans the same slices several tens of times after injection of contrast agent, which leads to much increased radiation dose and is inevitability of growing concern for radiation-induced cancer risk. Reducing the number of views in projection in combination of TV minimization reconstruction technique is being regarded as an option for radiation reduction. However, reconstruction artifacts due to insufficient number of X-ray projections becomes problematic especially when high contrast enhancement signals are present or patients motion occurred.

In this study, we present a novel reconstruction technique using contrast-adaptive TpV minimization that can reduce reconstruction artifacts effectively by using different p-norms in high contrast and low contrast objects. In the proposed method, high contrast components are first iteratively reconstructed using thresholded projection data and low pnorm total variation to reflect sparsness in both projection and reconstruction spaces . Next, projection data are modified to contain only low contrast objects by creating projection data of reconstructed high contrast components and subtracting them from original projection data. Then, the low contrast projection data are reconstructed by using relatively high p-norm TV minimization technique, and are combined with the reconstructed high contrast component images to produce final reconstructed images.

The proposed algorithm was applied to numerical phantom and a clinical data set of brain PCT exam, and the resultant images were compared with those using filtered back projection (FBP) and conventional TV reconstruction algorithm.

Our results shows the potential of the proposed algorithm for image quality improvement, which in turn may lead to dose reduction.

7961-104, Poster Session

Expectation maximization and total variation based model for computed tomography reconstruction from undersampled data

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Computerized tomography (CT) plays an important role in medical imaging, especially for diagnosis and therapy. However, higher radiation dose from CT will result in increasing of radiation exposure in the population. Therefore, the reduction of radiation from CT is an essential issue. Expectation maximization is an iterative method used for CT image reconstruction that maximizes the likelihood function under Poisson noise assumption. Total variation regularization is a technique used frequently in image processing to preserve edges, given the assumption that most images are piecewise constant. Here, we propose a method combining expectation maximization and total variation regularization, called EM+TV. This method can reconstruct a better image using fewer views, thus reducing the overall dose of radiation. The numerical results show the efficiency of the EM+TV method by comparison with the result obtained by filtered back projection.

7961-105, Poster Session

A comparison of four algorithms for metal artifact reduction in CT imaging

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Streak artifacts caused by the presence of metal have been a significant problem in CT imaging since its inception in 1972. With the fast evolving industry of medical devices, the level of metal objects implanted in patients is increasing annually. This correlates directly with an increased likelihood of encountering metal in a patient CT scan, thus necessitating the need for an effective and reproducible metal artifact reduction (MAR)

algorithm. Comparisons between MAR algorithms have been limited by the range of metal implants evaluated and the scope of anatomical regions from which patient data was taken. Although, the results of many methods are promising [1-4], the reproducibility of these results is key to providing more tangible evidence of their effectiveness. This study presents a direct comparison between the performances of four MAR algorithms: 3 non-iterative and one iterative method, all applied and compared to the original clinical DICOM images. The results of the evaluation indicated a negative mean score in almost all uses for two of the non-iterative methods, signifying an overall decrease in the diagnostic quality of the images, generally due to perceived loss of detail. One non-iterative algorithm showed a slight improvement. The iterative algorithm was superior in all studies by producing a considerable improvement in all uses.

7961-107, Poster Session

A study on regularization parameter choice for interior tomography based on truncated Hilbert transform

J. Wu, X. Mou, S. Tang, Xi'an Jiaotong Univ. (China)

Recently, the reconstruction method of interior tomography using truncated Hilbert transform via TSVD has been proposed, in which the regularization parameter is given directly. In fact, the selection of the regularization parameter that controls the trade-off between fidelity to the data and constraint on the reconstruction result is a primary problem in the regularization method. In this paper, we present a method of selecting the optimal regularization based on the L-curve for interior tomography based on truncated Hilbert transform. In this method, the optimal regularization parameter is computed theoretically using the maximum curvature of the L-curve . Root Mean Square Error (RMSE) of reconstructed image with respect to diffierent regularization parameters validate our selecting regularization parameter method. Moreover, we develop a Tikhonov regularization method in compasion to TSVD. Simulation results indicate that both of the two regularization methods with the optimal regularization paramters have good performances on the image quality for both cases of noise-free and noisy projections.

7961-108, Poster Session

Interior tomography from low-count local projections and associated Hilbert transform data

Q. Xu, Xi'an Jiaotong Univ. (China); H. Yu, Wake Forest Univ. (United States); X. Mou, Xi'an Jiaotong Univ. (China); G. Wang, Virginia Polytechnic Institute and State Univ. (United States)

This paper presents a statistical interior tomography approach combining an optimization of the truncated Hilbert transform (THT) data. With the introduction of the compressed sensing (CS) based interior tomography, a statistical iteration reconstruction (SIR) with a regularization of total variation (TV) minimization has been proposed to reconstruct the interior region of interest (ROI) with less noise from low-count local projections. After each update of the CS based SIR, a THT constraint can be joined by an optimizing strategy. Since the noisy differentiated back-projection (DBP) and its corresponding noise variance on each chord can be calculated from the Poisson projection data, an object function is developed to find an optimal THT of the ROI from the noisy DBP and the present reconstructed image. Then the inversion of this optimized THT on each chord is performed and the resulted ROI will be the initial image of next update by the CS based SIR. In addition, a parameter in the optimization of THT step can be used to determine the stopping rule of the iteration heuristically. Numerical simulation is implemented to evaluate the proposed approach. The results indicate that this approach can reconstruct an ROI with reducing the noise effectively.

7961-109, Poster Session

Compressed sensing algorithms for fan-beam CT image reconstruction

J. Zhang, J. Wang, G. Xu, Univ. of Wisconsin-Milwaukee (United States); J. Thibault, GE Healthcare (United States)

In this work, we investigated compressed sensing based algorithms for statistical iterative image reconstruction for fan beam CT. Specifically, we investigated two compressed sensing formulations/algorithms, the LP (linear programming or inequality constrained optimization) and QP (quadratic programming or unconstrained optimization) and studied their performances through simulation experiments. Our results indicate that the LP provides better reconstruction results and is computationally more efficient.

This work is important in that fan beam CT is the 2D version of an important 3D CT problem, multi-slice helical scan or cone beam CT. Using compressed sensing offers the potential to reconstruct images from a smaller number of projections or views, hence reduced patient radiation exposure. Furthermore, compressed sensing converts the reconstruction problem into one of convex optimization, which has a unique solution and can be solved efficiently (this is especially important for 3D cone beam CT).

7961-110, Poster Session

Low-dose dual-energy cone-beam CT using a total-variation minimization algorithm

J. Min, KAIST (Korea, Republic of) and Nano Focus Ray Inc. (Korea, Republic of); K. Kim, Nano Focus Ray Inc. (Korea, Republic of); G. Cho, S. Cho, KAIST (Korea, Republic of)

Dual-energy cone-beam CT is an important imaging modality in diagnostic applications, and may also find its use in other applications such as therapeutic image guidance. Despite of its clinical values, relatively high radiation dose of dual-energy scan may pose a challenge to its wide use. In this work, we investigated a low-dose, post-reconstruction type of dual-energy cone-beam CT (CBCT) using a total-variation minimization algorithm for image reconstruction. A micro-CT system and a contrast phantom were used for demonstrating the feasibility of the proposed method. We have reconstructed images of the phantom that are acceptable for post-reconstruction material decomposition from only 70 projections acquired at tube voltages of 40 kVp and 80 kVp each. Bone-only and soft-tissue-only images were successfully decomposed from the dual-energy images. We demonstrated a feasibility that a low-dose dual-energy CBCT can be realized via the proposed method by greatly reducing the number of projections.

7961-111, Poster Session

Refinement of motion correction strategies for lower-cost CT for under-resourced regions of the world

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This paper describes a recently developed post-acquisition motion correction strategy for application to lower-cost computed tomography (LCCT) for the developing world. Increased awareness regarding global health and its challenges has encouraged the development of more affordable healthcare options for underserved people worldwide. In regions such as Sub-Saharan Africa, intermediate level medical facilities may serve millions with inadequate or antiquated equipment due to financial limitations. In response, the authors have proposed a LCCT design which utilizes a standard chest x-ray examination room with

a digital flat panel detector (FPD). The (seated) patient rotates on a motorized stage between the fixed cone-beam source and FPD, and images are reconstructed using a Feldkamp algorithm for circular cone-beam scanning.

One of the most important proofs-of-concept in determining the feasibility of this system is the successful correction of undesirable motion. A 3D motion correction algorithm was developed in order to correct for potential patient motion, stage instabilities and detector misalignments which can all lead to motion artifacts in reconstructed images. Motion will be monitored by the radiographic position of fiducial markers to correct for rigid body motion in three dimensions. Based on simulation studies, projection images corrupted by motion were re-registered with average errors of -0.086 mm, -0.15 mm and 0.053 mm in the horizontal, vertical and depth dimensions, respectively. The overall absence of motion artifacts in motion-corrected reconstructions indicates that reasonable amounts of motion may be corrected using this novel technique without significant loss of image quality.

7961-112, Poster Session

Accelerating statistical image reconstruction algorithms for fan-beam x-ray CT using cloud computing

S. Srivastava, V. Sheinin, A. R. Rao, IBM Thomas J. Watson Research Ctr. (United States)

Statistical image reconstruction algorithms potentially offer many advantages to x-ray computed tomography (CT), e.g. lower radiation dose. But, their adoption in practical CT scanners requires extra computation power, which is traditionally provided by incorporating additional computing hardware (e.g. CPU-clusters, GPUs, FPGAs etc.) into a scanner. An alternative solution is to access the required computation power over the internet from a cloud computing service, which is orders-of-magnitude more cost-effective. This is because users only pay a small pay-as-you-go fee for the computation resources used (i.e. CPU time, storage etc.), and completely avoid purchase, maintenance and upgrade costs. In this paper, we investigate the benefits and shortcomings of using cloud computing for statistical image reconstruction. We parallelized the most time-consuming parts of our application, the forward and back projectors, using MapReduce, the standard parallelization library on clouds. From preliminary investigations, we found that a large speedup is possible at a very low cost. But, communication overheads inside MapReduce can limit the maximum speedup, and a better MapReduce implementation might become necessary in the future. All the experiments for this paper, including development and testing, were completed on the Amazon Elastic Compute Cloud (EC2) for less than $20.

7961-113, Poster Session

Quantitative evaluation method of noise texture for iteratively reconstructed x-ray CT images

P. Theriault Lauzier, J. Tang, G. Chen, Univ. of Wisconsin-Madison (United States)

Recently, iterative image reconstruction algorithms have been extensively studied in x-ray CT in order to produce images with lower noise variance and high spatial resolution. However, the images thus reconstructed often have unnatural image noise textures, the potential impact of which on diagnostic accuracy is still unknown. This is particularly pronounced in total-variation-minimization-based image reconstruction where the noise background often manifests itself as patchy artifacts. In this paper, a quantitative noise texture evaluation metric, the excess kurtosis S_k, is introduced to evaluate the deviation of the noise correlation from the commonly observed normal distribution. Using the excess kurtosis index, three image reconstruciton algorithms are studied: the conventional filtered backprojection (FBP) algorithm, least-squares method (LSQ) and TV-based compressive sampling algorithm (TVCS). It was demonstrated that the kurtosis index is mostly invariant in the FBP algorithm when the number of projections are changed. When fewer projections are used, more and more streaking artifacts appear in the reconstructed images. Using TVCS, the undersampling streaking artifacts are mitigated, but the kurtosis increases in value. The results demonstrate an inverse correlation between the noise level and the kurtosis. The same noise texture quantification method can also be utilized to evaluate the performance of other iterative image reconstruction algorithms.

7961-114, Poster Session

An efficient scatter correction method based on pre-reconstructed images of contrast enhancement and sparse-viewed Monte Carlo simulation

H. Yan, X. Mou, Xi'an Jiaotong Univ. (China)

Strategies battling with the scattered x-photons in CB imaging are usually performed in the raw-data space (before logarithm), seldom Radon-space based. To our knowledge, no study is concerning the scatter correction by interconnecting the raw-data space and Radon space.

In this paper, we make a study on the scatter correction method in Radon space, which is based on the motivation to enhance the contrast of the scatter-polluted views. The key finding of this paper is stated as follows: the ratio of Is (scatter) to Ip+s (primary plus scatter) could be approximated by a basic function of the logarithm processed data, log(max (Is)/Ip+s). Based on this finding, we propose an exemplary method named as Pre-Reconstruction of the Images with Contrast-Enhancement (PRICE). Furthermore, a hybrid correction (PRICE-MC) is developed by integrating a super sparse viewed, non-iterative MC method with PRICE.

In the simulations, humanlike phantom Zubal is adopted. Firstly, the key finding is validated by comparing real and estimated Is/(Ip+s)plotted along three different locations in two typical views. Secondly, the PRICE and PRICE-MC algorithm is evaluated qualitatively by the reconstructed/ difference images of the axial, sagittal and coronal views; further evaluation is performed quantitatively by a factor of image quantity (Q), which is enhanced by PRICE from 0 to 0.6577, 0.6762, 0.7137 for the central slices in axial, sagittal and coronal views respectively, and further to 0.8118, 0.7964, 0.7890 by PRICE-MC.

The main contributions of this paper is: 1.The finding that scatter-polluted raw-data can be approximated by its counterpart in Radon space, which is promising in developing efficient scatter correction methods; and the finding itself, still has room for improvement (under research). 2. Based on 1, preliminary examples (PRICE, PRICE+MC) with good performances are illustrated in this paper. Specially, the rapidness and efficiency of PRICE might make it being a promising raw-data preprocessing technique.

7961-115, Poster Session

Task-based comparative study on iterative image reconstruction methods for limited-angle x-ray tomography

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For x-ray tomography that has available only projection views from a limited angular span, such as a tomosynthesis system, the image reconstruction problem is ill-posed. Reconstruction methods play an important role in optimizing the image quality for human interpretation. In this work we compare three popular iterative image reconstruction methods that have been applied to digital tomosynthesis systems: the simultaneous algebraic reconstruction technique (SART), the Maximum-Likelihood expectation-maximization (MLEM) and the Total-variation regularized least-square reconstruction method (TVLS). Quality of the

images reconstructed from these three methods is assessed through task-based performance. Two tasks are considered in this work: lesion detection and shape discrimination. Area under the ROC curve (AUC) is used as the figure-of-merit. Our simulation results indicate that TVLS and SART perform very similarly and better than the MLEM in terms of lesion detectability, while the MLEM performs better than the other two in terms of shape discrimination ability.

7961-116, Poster Session

limited data tomographic image reconstruction via dual formulation of total variation minimization

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X-ray mammography is the primary imaging modality for breast cancer screening. For the dense breast, however, the mammogram is usually difficult to read due to tissue overlap problem that is inherent in 2-D projection imaging. The digital breast tomosynthesis (DBT) that measures several low dose projections over a limited angle range may be an alternative modality for breast imaging. There are two types of difficulty for reconstructing the projected images into a 3-D volume set: an aliasing artifact due to the restricted view angle, and the noise corruption for low dose imaging. To overcome these problems, a novel reconstruction algorithm using total variation (TV) regularization is presented. Inspired by the dual formulation of TV minimization in denoising and deblurring problems, we derived a gradient-type algorithm based on statistical model of X-ray tomography. The objective function is comprised of a surrogate function for Poisson log-likelihood and a TV regularization term. The gradient of the objective function can be easily calculated using simple operations in terms of auxiliary variables. After a descending step, the data fidelity term is renewed in each iteration. Since the proposed algorithm can be implemented without sophisticated operations such as matrix inverse, it provides an efficient way to include the TV regularization in statistical reconstruction method, which results in fast and robust estimation for low dose projections over the limited angle range. Initial numerical results confirm our finding.

7961-117, Poster Session

Data-driven pose correction for cone-beam CT with analytic and iterative reconstruction methods

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A precise knowledge of the geometry information of a cone-beam CT is required for high quality image reconstruction. In some applications, however, the acquisition geometry is either not well characterized or not repeatable, for example, in the case of gantry vibration and patient motion. An offline correction using a calibration pattern and an online calibration using an external tracking system may be used to measure and correct CT geometry parameters during reconstruction. Both approaches have limitations though. A new method is proposed in this paper to estimate pose parameters using the acquired cone beam projection data only. During the pose estimation process each 2D projection data is registered to the 3D volume reconstructed from the current, inaccurate pose estimate. Pose parameters are then corrected incrementally using the registration results. Applying this 2D-3D registration method to the FDK reconstruction method, we are able to estimate rotational parameters to within an average total angular deviation of 0.5 degrees, and center-of-rotation to an average of 0.02% of the source-to-detector distance (SID) in the detector plane. The image quality of CT reconstructions is comparable to those using exact geometry. This scheme will be extended to iterative reconstruction methods such as SART. Iterative reconstruction methods are expected to generate better results because of their robustness to noise and gantry variations. Results from analytic and iterative reconstruction methods will be compared in the full manuscript.

7961-118, Poster Session

A simple image based method for obtaining electron density and atomic number in dual energy CT

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The extraction of electron density and atomic number information in CT is possible when image values can be sampled using two different effective energies. The foundation for this extraction lies in the ability to express the linear attenuation coefficient using two basis functions over the diagnostic energy range. Material basis functions separate images into clinically familiar quantities such as `bone images' and `soft tissue images'. Physically, all basis function choices represent the expression of the linear attenuation coefficient in terms of a photoelectric and a Compton scattering term. The purpose of this work is to demonstrate how electron density and atomic number images can be generated from material basis images decomposed in image space. It is shown that the weighted sum of two basis images yields an electron density image where the weights for each basis image are the electron density of that basis image's basis material. Using the electron density image, effective atomic number information can also be obtained. These methods are performed solely in the image domain; no spectrum information or the detector energy response is required.

7961-119, Poster Session

A scatter artifact reduction technique in dual-energy computed tomography systems

J. Fan, N. Chandra, J. Hsieh, GE Healthcare (United States)

Spectral CT research and development has recently become a hot topic in industry and in academia. Different approaches have been developed for spectral CT imaging. As a result of the capability to generate monochromatic-energy images, beam hardening artifacts have been largely reduced. However, X-ray scatter is still present, and the associated scatter artifact can still be present in the base material images. This paper proposes an approach for scatter artifact reduction for dual-energy CT. Phantoms as well as clinical data have been evaluated to demonstrate the effectiveness of this approach.

This paper attempts to address the correction of the X-ray scatter artifacts in the material images of dual-energy CT. The approach can be briefly described as the following. The information of water-like soft tissue and high-attenuation materials (including human bone, metal implants, etc.) are retrieved from monochromatic images. The estimated high-attenuation information is forward projected to generate the corresponding projection data. Polynomial-form corrections are applied to modify the projection data for artifact modeling. Then a FBP is applied to generate a base correction image. The correlation information about the relevant amount of artifact in the two base material images is estimated. Finally, the base correction image and the estimation of the correlation information are applied together to correct for the two base material images separately. Phantoms as well as clinical data have been evaluated to demonstrate the effectiveness of our approach.

This algorithm is not limited to any specific dual-energy approach and can be applied on various dual-energy techniques.

7961-120, Poster Session

Calculation of the MTF and NPS of CT: a proposal to the IEC

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The current standard method for characterizing noise in CT scanners is based on the pixel standard deviation of the CT image of a water-equivalent uniform phantom. However, the standard deviation does not account for correlations in the noise. Therefore, we are going to propose to the IEC to analyze the CT noise by calculating the Fourier based noise power spectrum (NPS) that translates the noise correlations to a function of the spatial frequency. The deterministic properties of CT scanners are suggested to be still characterized by the Fourier based modulation transfer function (MTF). By accounting for the spatial correlations in both the stochastic and deterministic description of an imaging system, the signal and noise transfer through the system is estimated more accurately. Furthermore by accounting for the correlations, misleading estimates of the system SNR can be avoided. In this paper we present a proposal to the IEC for estimating the MTF and the NPS of a CT scanner in the axial plane. Since the Fourier based methods make limiting assumptions such as shift invariance and wide sense stationarity, we additionally compared the results to an image-space based approach, for which we calculated the H matrix, the covariance matrix and their respective eigenanalyses. By following methods available in current literature, we used a tungsten wire in air as a point source and a standard water phantom for the noise images. Images were taken at four different mAs-settings and reconstructed with four different filters.

7961-121, Poster Session

XCAT/DRASIM: a realistic CT/human-model simulation package

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The aim of this research is to combine the 4-D XCAT phantom, the NURBS surface ray-tracing algorithm, and the DRASIM (Siemens Healthcare) CT-data simulation program into a complete CT/human-model simulation package. Unlike other CT simulation tools which are based on simple mathematical primitives or voxelized phantoms, this new simulation package has the advantage of utilizing a realistic model of human anatomy and physiological motions without voxelization and with accurate modeling of the characteristics of clinical CT systems. First, we incorporated the 4-D XCAT anatomy and motion models into DRASIM by implementing a new library which consists of functions to read-in the NURBS surfaces, material properties, and overlapping order of the anatomical objects in the XCAT phantom. Second, we incorporated a ray-tracing algorithm for line integral calculation in DRASIM by computing the intersection points of a ray casting from the x-ray source to the detector elements through the NURBS surfaces of multiple XCAT objects along its path. Third, we evaluated the integrated simulation package by performing a series of simulations of multiple x-ray projections from different views followed by image reconstruction. The initial simulations are promising by qualitative evaluation. Quantitative evaluation of the simulated data with experimental measurements using real CT scanners is underway. In conclusion, we have developed a unique CT/human-model simulation package which has great potential to be a valuable tool in the design and optimization of CT scanners, and the development of scanning protocols and image reconstruction methods for improving CT image quality and reducing radiation dose.

7961-122, Poster Session

Longitudinal tube modulation for chest and abdominal CT examinations: impact on effective patient doses calculations

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Purpose: In multi-slice CT, manufacturers have implemented automatic tube current modulation (TCM) algorithms. These adjust tube current in the x-y plane (angular modulation) and/or along the z-axis (z-axis modulation) according to the size and attenuation of the scanned body part. Current methods for estimating effective dose (ED) values in CT do not account for such new developments. This study investigated the need to take TCM into account when calculating ED values, using clinical data.

Methods: The effect of TCM algorithms as implemented on GE BrightSpeed 16 and Siemens Somatom Sensation 64 was investigated. Here, only z-axis modulation was addressed, considering thorax and abdomen CT examinations collected from 238 patients (adults and children). Commercially available CT dosimetry software (CT expo v.1.6) was used to compute EDTCM (ED accounting for TCM) as the sum of ED of successive slices acquired using modulated mA values and compare these EDTCM to patient ED estimated using average mA of all slices.

Results and Conclusions: The proposed method is relatively simple and uses as input: the parameters of each protocol, a fitted polynomial function of weighting factors for each slice along the scan length and mA values of the individual patient examination. Preliminary results show that z-axis modulation has an impact on ED and therefore on ED/DLP conversion coefficients. The proposed method will be applied to all patient data collected, in order to calculate average specific deviations of EDTCM from ED. This could be compared with results obtained from previous studies on voxel or mathematical phantoms.

7961-123, Poster Session

Dosimetric quality control of Eclipse treatment planning system using pelvic and thoracic digital test objects

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Last year, we demonstrated the feasibility of a new method to perform dosimetric quality control of Treatment Planning Systems in radiotherapy, this method is based on Monte-Carlo simulations and using anatomical Digital Test Objects (DTOs). The pelvic DTO was used in order to assess this new method on an ECLIPSE VARIAN Treatment Planning System. Large dose variations were observed particularly in air and bone equivalent material.

In this current work, we discuss the results of the previous paper and we provide an explanation for observed dose differences. The Varian Eclipse (Anisotropic Analytical) algorithm was investigated. Monte Carlo simulations (MC) were performed with a PENELOPE code version 2003. To increase efficiency of MC simulations, we have used our parallelized version based on the standard MPI (Message Passing Interface). The parallel code has been run on a 32-processor SGI cluster. The study was carried out using two DTOs: pelvis and thorax and was performed for low- and high-energy photon beams (6 and 18MV) on 2100CD Varian linear accelerator. Two squares fields (10×10 and 3x3 cm^2) were used. Assuming the MC data as reference, γ and χ index analyses were carried out. For this study, a distance to agreement was set to 7mm while the dose difference was set to 5%. When using Monte Carlo PENELOPE, the

absorbed dose is computed to the medium, however the TPS computes dose to water . Results show a strong consistency between ECLIPSE and MC calculations on the beam axis.

7961-124, Poster Session

Estimation of organ and effective dose to the patient during spinal surgery with a cone-beam O-arm system

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The mobile intraoperative O-arm imaging system is comprised of fluoroscopy and cone-beam CT and has been shown to provide great clinical value for surgery. The purpose of the study was to estimate organ and effective dose to the patient for the cone-beam O-arm system in spinal surgery. The absorbed dose to radiosensitive organs and effective dose were calculated on mathematically simulated hermaphrodite phantom corresponding to a 15-year-old patient using PCXMC 2.0. Radiation doses were calculated at every 15º of the x-ray tube projection angle at two regions: thoracic spine and lumbar spine. Two different scan settings were investigated: 120 kV/128 mAs (standard) and 80 kV/80 mAs (low-dose). The effect on effective dose by changing the number of simulated projection angles (24, 12 and 4) was investigated. The highest absorbed doses were obtained in the breast, lungs (thoracic spine) and stomach (lumbar spine). The absorbed doses to thyroid gland were 7 times higher in standard scan than in low-dose scan. Corresponding values for breasts, stomach and gonads were 4, 5, and 6 times higher. The effective doses using standard settings were 5 times higher than those delivered with low-dose settings (2-3 scans: 7.9-12.3 mSv versus 1.5-2.4 mSv). There was no difference in effective dose using 24 or 12 projection angles. 4 projection angles at every 90º was not enough to accurate simulate the x-ray tube rotating around the patient. Our conclusion is that the O-arm has the potential to deliver high radiation doses; consequently there is a strong need to optimize the clinical scan protocols.

7961-125, Poster Session

Monte Carlo modeling of the scatter radiation dose distribution

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Introduction: The radiation dose received by personnel within the procedure room depends on the imaging geometry, patient size and location within the room. Monte Carlo methods offer a powerful method to compute the scatter radiation dose distribution for any arrangement of imaging geometry, patient size and personnel location.

Method: MCNP was used to model the scatter radiation air kerma (AK) per unit kerma area product (KAP) distribution around a 24 cm diameter water cylinder irradiated with monoenergetic x-rays. Scatter AK/KAP was obtained for three regions surrounding the water cylinder: below the water cylinder (backscatter), above the water cylinder (forward scatter) and to the sides of the water cylinder (side scatter).

Results: Immediately above and below the water cylinder and in the side scatter region, scatter AK/KAP decreased with the inverse square of the distance. For z-planes further away, the decrease was exponential. Changes in scatter AK/KAP with x-ray energy were relatively small, generally < 20%. The ratio of forward to back scatter AK/KAP was lowest at 60 keV and highest at 120 keV. Scatter AK/KAP at all locations around the phantom was generally below 10-4.

Conclusion: The scatter AK/KAP distribution around the 24 cm diameter water cylinder decreased with the inverse square of the distance in z-planes near or containing the water cylinder and decreases exponentially for z-planes further away from the water cylinder. Little variation was seen with x-ray energy changes. At low energies the scatter AK/KAP was highest in the backscatter regions and decreased with increasing x-ray energy.

7961-126, Poster Session

A reference implementation of the standardized exposure index (EI)

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An Exposure Index (EI) is a measure of the dose received by an image detector. The EI for a given system is typically established and reported by the system manufacturer and different vendors have implemented variations of the same fundamental metric. Medical Physicists require easy-to-use and consistent tools to measure the EI for any anatomy and independent of the CR/DR vendor. AAPM TG116 was commissioned to provide a standardized EI metric to enable objective comparisons of dose used in digital x-ray imaging systems from different vendors. The purpose of this work was to develop reference implementation of the TG116 standard is to enable measurement of the EI independent of the vendor, for any given anatomy, and to investigate inconsistencies in the EI metric for CR systems.

7961-127, Poster Session

Fluence estimation by deconvolution via l1-norm minimization

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Advances in radiotherapy irradiation techniques have led to very complex treatments requiring for a more stringent control. The dosimetric properties of electronic portal imaging devices (EPID) encouraged their use for treatment verification. Two main approaches have been proposed: the forward approach, where measured portal dose images are compared to predicted dose images and the backward approach, where EPID images are used to estimate the dose delivered to the patient. Both approaches need EPID images to be converted into a fluence distribution by deconvolution. However, deconvolution is an ill-posed problem which is very sensitive to small variations on input data. This study presents the application of a deconvolution method based on l1-norm minimization; this is a method known for being very stable while working with noisy data. The algorithm was first evaluated on synthetic images with different noise levels, the results were satisfactory. Deconvolution algorithm was then applied to experimental portal images; the required EPID response kernel and energy fluence images were computed by Monte-Carlo calculation, accelerator treatment head and EPID models had already been commissioned in a previous work. The obtained fluence images were in good agreement with simulated fluence images.

This deconvolution algorithm may be generalized to an inverse problem with a general operator, where image formation is not longer modeled by a convolution but by a linear operation that might be seen as a position-dependent convolution. Moreover, this procedure would be detector independent and could be used for any detector type provided its response function is known.

7961-128, Poster Session

A novel noise suppression solution in cone-beam CT images

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(United States); Q. Lin, Y. Liu, Z. J. Liang, Stony Brook Univ. (United States)

In modern computed tomography (CT), filtered-backprojection algorithms, such as Feldkamp-Davis-Kress (FDK), have been employed to obtain the reconstructions under cone-beam geometry. While, due to the spatially invariant interpolation process and pre-weighting factor adopted in numerical implementation of the algorithms, nonuniform noise propagation have been observed across the field-of-view. In this study, instead of using spatially invariant interpolation, we consider the spatially variant weighting to compensate for the nonuniformity.

More specifically, the pre-weighting factor 1/U2 in FDK algorithm with ramp filter and invariant interpolation causes a significant non-uniform noise variance in the cone-beam CT (CBCT) images reconstructions. This will result the different noise distribution in the filed of view even in the same CT data noise property. In this study, we develop a spatially variant volume weighting method toward the nonuniformity in CBCT image reconstruction. Numerical implementation of FDK algorithm with proposed method shows significant improvement of the nonuniformity in the filed of view compared to that use conventional linear/spatial invariant interpolation. The proposed method can also be applied to other reconstruction algorithms. More quantitative demonstration of the effectiveness of this work is currently under investigation.

7961-129, Poster Session

Noise reduction by projection direction dependent diffusion for low dose x-ray fan-beam computed tomography

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In this paper, we propose a novel method to reduce the noise in computed tomography (CT) imaging. Firstly, inverse Radon transforms are induced for a family of differentiated projections. Then, diffusion partial differential equation (PDE) is generalized from image space to projection space for parallel-beam geometry. Thirdly, the diffusion PDE is further induced from parallel-beam geometry to fan-beam geometry. Finally, projection direction dependent diffusion is developed to smooth CT noise, which is due to quantum variation during low dose exposure in medical x-ray CT (XCT) system. The noise reduction scheme processes projection data iteratively and dependently on projecting orientation, which is followed by a general CT reconstruction. Numerical experiments by computer-generated projections have demonstrated its usefulness in the noise reduction of low dose x-ray CT image.

7961-130, Poster Session

Radiation dose reduction in computed tomography (CT) using a novel implementation of wavelet denoising in low tube current acquisitions

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Radiation dose reduction remains at the forefront of research in computed tomography. X-ray tube parameters such as tube current can be lowered to reduce dose; however, images become prohibitively noisy when the tube current is too low. Traditional methods of noise reduction such as low-pass Fourier filtering techniques are able to reduce noise, but image quality suffers as high detail information is lost. Studies with the wavelet transform have been heralded to succeed where Fourier techniques have failed, namely, in the ability to reduce noise while preserving high detail information. However, these wavelet techniques have the tendency to create artificial noise textures, due to the high nonlinearity of the wavelet denoising process, which are undesirable from a diagnostic perspective. This work presents a novel implementation of wavelet denoising that is able to achieve aggressive noise reduction, while still preserving spatial resolution and the noise texture of traditional filtered backprojection images. Specifically, the proposed technique begins by low-pass filtering the original image (which can occur in the spatial direction, temporal direction, or both). Then, the low-pass filtered version is subtracted from the original image to yield a difference image, which contains edge structure and noise. The wavelet denoising technique is applied to the difference image, and the resulting denoised difference image is added back to the low-pass filtered version to yield the final image. The technique is validated on three datasets (Catphan phantom, time-resolved swine heart scan, time-resolved canine head scan) acquired at a series of tube currents.

7961-131, Poster Session

Noise characteristics of x-ray differential phase contrast CT

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The noise characteristics of x-ray differential phase contrast computed tomography (DPC-CT) were investigated. Both theoretical derivation and experimental results demonstrated that the dependence of noise variance on spatial resolution in DPC-CT follows an inverse linear law. This behavior distinguishes DPC-CT from conventional absorption based x-ray CT, where the noise variance varies inversely with the cube of the spatial resolution. This anomalous noise behavior in DPC-CT is due to the Hilbert filtering kernel used in the CT reconstruction algorithm, which equally weights all spatial frequency content. Additionally, we demonstrate that the noise power of DPC-CT is scaled by the inverse of spatial frequency and is highly concentrated at the low spatial frequencies, whereas conventional absorption CT increases in power at the high spatial frequencies.

7961-132, Poster Session

Contrast-to-noise of a non-ideal, multi-bin, photon counting x-ray detector

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Experimental Measurements and Monte Carlo simulation is used to determine the impact of the spectral performance degradation in a photon counting detector due to electronic noise, low energy tailing and pile-up at high count rate. The contrast-to-noise (CNR) of various materials is calculated using multiple realizations of the transmission experiment. It is optimized for weighting factors over the bins and calculated for various energy threshold settings of the bins. Comparison is made to single bin photon counting and energy integration detectors. In the case of water imaging, a realistic single-bin photon counting detector with energy resolution of 10 keV yields a 10% CNR2 benefit. The CNR2 benefit for iodine imaging is a factor of 1.9. These benefits of multi-bin photon counting vanish at about 40-60% tail fraction and 20-30 keV RMS noise. The CNR2 benefit also decreases as count rate approaches the maximum periodic rate (MPR) associated with pile-up. The spectral information is available to higher rates when three energy bins are use and optimally weighted.

7961-134, Poster Session

MCNP simulation of primary and scatter radiation dose distribution in water phantom

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Purpose: Scattered radiation during radiological examinations causes the increase in patient dose as well as reduction in image quality. In this study, we investigated the distribution and contribution of the primary dose and scatter dose which are caused by the direct radiation and indirect radiation in water phantom, respectively.

Method: A simple irradiation geometry consisting of an x-ray source, DAP chamber, water cylinder (diameter = 17cm, 21cm, 24cm, 28cm, 30cm) and image intensifier was modeled using MCNP5/MCNPX 2.6.0. X-ray spectrum data (60, 80, 100 and 120 kVp) were generated using software XCOMP3R. Radiation doses inside the water cylinder (Dwater), free-in-air Air Kerma (AKfree-in-air), and absorbed energy to the directly irradiated volume (Ep) and indirectly irradiated volume (Es) were obtained.

Results: The average scattered energy deposition percentage (Es/(Ep+Es)) is 27%. At a fixed x-ray tube voltage of 80 kVp, increasing the water cylinder diameter from 17cm to 30cm increased the Es/(Ep+Es) ratio by ~50%; At a fixed water cylinder diameter of 24cm, increasing the tube voltage from 60 kVp to 120 kVp increased the Es/(Ep+Es) ratio by ~12%. At 80 kVp, the average Dwater/AKfree-in-air near the x-ray entrance point is ~1.3, and the ratio of Dwater near the entrance point to the Dwater near the exit point increases from ~26 for 17cm water cylinder to ~289 for 30cm water cylinder.

Conclusion : The absorbed energy from scattered radiation was between 20-33% of the total energy absorbed by the water cylinder, and was affected more by patient size than x-ray beam energy.

7961-135, Poster Session

Noise reduction in dual-source CT scanning

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With dual source CT, special attention has to be paid to scattered radiation. X-ray quanta from the second source (tube B) get scattered from the object in the scan field and are registered by the first detector (detector A) and vice versa (“cross scattered radiation”). Depending on object and CT scan parameters, the ratio of scattered radiation intensity s over primary radiation intensity p can even exceed unity. In order to restore contrast and avoid artefacts, the scattered radiation signal needs to be determined and subtracted from the measured signal. However, the thus corrected projections experience a noise increase proportional to sqrt(1+s/p). In CT, line integrals are often measured along the same trajectory, but from opposite directions. With dual source CT, the rays within such a pair of projection data can be differently affected by cross-scattered radiation. Typically, rays which are complementary to those that experience maximum scattered intensity are affected by rather low scattered intensity. The current work presents a noise-weighted reconstruction scheme, depending on the scatter-to-primary ratio s/p, which leads to minimum noise increase in these situations. The proposed weighting scheme can also be combined with other means of noise reduction in the case of scattered radiation correction, e.g. a subsequent spatial signal filtering. The effect of the weighting scheme is evaluated with phantom scans using typical dual source CT parameter settings. For semi-anthropomorphic phantoms with large diameters, the proposed projection weighting leads to a projection noise decrease of up to 10% compared to a scheme with equal projection weighting.

7961-136, Poster Session

Relative dose in dual energy fast-kVp switching and conventional kVp imaging: spatial frequency dependent noise characteristics and low contrast imaging

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Dual energy computed tomography offers unique diagnostic value by enabling access to material density, effective atomic number, and energy specific spectral characteristics, which remained indeterminate with conventional kVp imaging. Gemstone Spectral Imaging (GSI) is one of the dual energy methods based on fast kVp switching between two x-ray spectra, 80 kVp and 140 kVp nominal, in adjacent projections. The purpose of this study was to compare relative dose between GSI monochromatic and conventional kVp imaging for equivalent image noise characteristics. A spatial-frequency domain noise power spectrum (NPS) was used as a more complete noise descriptor for the comparison of the two image types. Uniform 20cm water phantom images from GSI and conventional 120 kVp scans were used for NPS calculation. In addition, a low contrast imaging study of the two image types with equivalent noise characteristics was conducted for contrast-to-noise-ratio (CNR) and low contrast detectability (LCD) in the Catphan600® phantom. From three GSI presets ranging from medium to low dose, we observed that conventional 120kVp scan requires ~ 7% - 18% increase in dose to match the noise characteristics in optimal noise GSI monochromatic image; and that the 65 keV monochromatic image CNR for a 0.5% contrast object is 22% higher compared to corresponding 120 kVp scan. Optimal use of the two energy spectra within GSI results in reduced noise and improved CNR in the monochromatic images, indicating the potential for use of this image type in routine clinical applications.

7961-137, Poster Session

Determination of 3D flow velocity distributions from single-plane angiographic sequences

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Understanding 3D flow velocity fields can be valuable during interventional procedures. As a step toward this goal, we are developing methods to calculate 3D flow fields from single-plane angiographic sequences. The vessel geometry is selected. Flow fields are generated based on either laminar flow conditions or CFD results. X-ray-attenuating contrast is propagated through the vessel using the flow fields. Angiograms are generated at 30 frames/second using ray-casting. Data are extracted from the angiograms along lines perpendicular to the vessel axis to generate vessel profiles. The conversion from image intensity to contrast pathlength is determined. The contrast pathlength is calculated for each vessel-profile point and is centered on the central plane in the vessel, to generate a 3D contrast distribution in the vessel. This procedure is repeated for each acquired angiogram. Corresponding points on the surface of the calculated contrast distributions are established for temporally adjacent distributions. Vectors and velocities between corresponding points are calculated, providing the 3D velocity flow field in the vessel lumen. Simulations for steady flow conditions for straight vessels, curved (in-plane) vessels, and vessels with stenoses, for noiseless and noisy (10% peak contrast) angiograms were performed. The calculated and simulated 3D contrast distributions agree well for both noiseless and noisy conditions (errors < 2 voxels ~ 0.2 mm). Average absolute error of the calculated 3D flow velocities is less than 7%. These promising initial results indicate that this technique may form the basis for calculating 3D-contrast and 3D-flow-velocity distributions from single-plane angiographic sequences.

7961-138, Poster Session

Susceptibility quantification in MRI using modified conjugate gradient least square method

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MR susceptometry provides a new approach to enhance contrast in MR imaging and to quantify substances such as iron, calcium, blood oxygenation in various organs for the clinical diagnosis of many diseases. Susceptibility is closely related to the magnetic field inhomogeneity in MRI, and calculation of susceptibility from the measured magnetic field is an ill-posed inverse problem. Conjugate gradient least square (CGLS) method with Tikhonov regularization is a powerful tool to solve the inverse problems. However, the estimated quantity in CGLS method is usually in one-dimensional (e.g., a column vector) while the most of MR data are in the form of three dimensions. In this work, the least square problem is modified to enable the calculation of susceptibility directly from three-dimensional MR phase maps, which has the benefit of reducing the size of associated matrices and usage of computer memories. Numerical simulations were used to find the proper regularization parameters and study the influence of different noise levels of the magnetic field on the regularization parameters. Experiments of superparamagnetic iron oxide phantom were also conducted. Both of the results demonstrate the validation and accuracy of this method.

7961-139, Poster Session

Direct reconstruction of T1 from k-space using a radial saturation-recovery sequence

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Contrast agent concentration ([CA]) must be known accurately to quantify dynamic contrast-enhanced (DCE) MR imaging. Accurate concentrations can be obtained if the longitudinal relaxation rate constant T1 is known both pre- and post-contrast injection. Post-contrast, signal intensity in the images is often saturated and an approximation to T1 can be difficult to obtain. One method that has been proposed for accurate T1 estimation effectively acquires multiple images with different effective saturation recovery times (eSRTs) and fits the images to the equation for T1 recovery to obtain T1 values. This was done with a radial saturation-recovery sequence for 2D imaging of myocardial perfusion with DCE MRI. This multi-SRT method assumes for each image that the signal intensity is constant for different readouts. Here this assumption is not necessary as a model-based reconstruction method is proposed that directly reconstructs an image of T1 values from k-space. The magnetization for each ray at each readout pulse is modeled in the reconstruction with Bloch equations. Computer simulations based on a 72 ray cardiac DCE MRI acquisition were used to test the method. The direct model-based reconstruction gave accurate T1 values and was more accurate than the multi-SRT method, which used three sub-images.

7961-140, Poster Session

Histogram analysis of ADC in brain tumor patients

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At various stage of progression, most brain tumors are not homogenous. In this presentation, we retrospectively studied the distribution of ADC values inside tumor volume during the course of tumor treatment and progression for a selective group of patients who underwent an anti-VEGF trial. Complete MRI studies were obtained for this selected group of patients including pre- and multiple follow-up, post-treatment imaging studies. In each MRI imaging study, a total of ten scan series were obtained as a standard protocol which includes T1, T2, T1-post contrast, FLAIR and DTI derived volumes (ADC, FA etc.) for each visit. All scan series (T1, T2, FLAIR, post-contrast T1) were registered to the corresponding DTI scan at the first visit. Conventionally, hyper-intensity regions on T1-post contrast MRI scan is believed to represent the core tumor region and tumor regions highlighted by FLAIR will overestimate the true tumor size. Thus we annotated tumor regions on the T1-post contrast scan and ADC intensity values for pixels were extracted inside tumor regions as defined on the T1-post scan. After that, we fit a mixture Gaussian (MG) model for the extracted pixels using the Expectation-Maximization (EM) algorithm, which produced a set of parameters (mean, various and mixture coefficients) for the MG model. This procedure was performed for each visits resulting in a series of GM parameters. We studied the parameters fitted for ADC and see if they can be used as indicators for tumor progression. Additionally, we studied the ADC characteristics in the peri-tumoral region as identified by hyper-intensity on FLAIR scans. The results show that ADC histogram analysis of the tumor region supports the two compartment model that suggests the low ADC value sub-region corresponding to densely packed cancer cell while the higher ADC value region corresponding to a mixture of viable and necrotic cells with superimposed edema. Careful studies of the composition and relative volume of the two compartments in tumor region may provide some insights in the early assessment of tumor response to therapy for recurrence brain cancer patients.

7961-141, Poster Session

The development and application of calculated readout in spectral parallelism in magnetic resonance imaging

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In magnetic resonance imaging (MRI), an object within a field-of-view (FOV) is spatially encoded with a broad spectrum of frequency components generating signals that decohere with one another to create a decaying echo with a large peak amplitude. The echo is short and decays at a rapid rate relative to the readout period when performing high resolution imaging of a sizable object where many frequency components are encoded resulting in faster decoherence of the generated signals. This makes it more difficult to resolve fine details as the echo quickly decays down to the quantization limit. Samples collected away from the peak signal, which are required to produce high resolution images, have very low amplitudes and therefore, poor dynamic range.

We propose a novel data acquisition system, Calculated Readout in Spectral Parallelism (CRISP), that spectrally separates the radio frequency (RF) signal into multiple narrowband channels before digitization. The frequency bandwidth of each channel is smaller than the FOV and centred over a part of the image with minimal overlap with the other channels. The power of the corresponding temporal signal in each channel is reduced and spread across a broader region in time with a slower decay rate. This allows the signal from each channel to be independently amplified such that a larger portion of the signal is digitized at higher bits. Therefore, the dynamic range of the signal is improved and sensitivity to quantization noise is reduced. We present a realization of CRISP using inexpensive analog filters and preliminary results from high resolution images.

7961-142, Poster Session

Voxel magnetic field disturbance from remote vasculature in BOLD fMRI

Z. Chen, Z. Chen, V. D. Calhoun, The Mind Research Network (United States)

The magnetic field influence of the blood magnetization in a strong magnetic field is non-local. In the electromagnetic dipole model, a magnetic dipole decreases outwardly by 1/r3 (r: radial distance). Considering the magnetized blood with vessels as a collection of magnetic dipoles, we can use 3D convolution (with the kernel of a Green's function) to calculate the magnetic field contribution from remote vasculature in blood oxygenation level dependent (BOLD) fMRI. A 3D Fourier transform technique can be used to efficiently calculate the blood-susceptibility-induced magnetic field disturbance. The local summation property of the convolution allows us to focus on a small part in the convolutional kernel space, therefore we can address effect of the remote vasculature on a voxel of interest (VOI). We evaluate the effect of remote vasculature on BOLD magnetic field disturbance over a VOI with respect to remote distance, orientation, and vasculature. The spatial symmetry and asymmetry of the vasculatures outside the VOI will also influence the distribution of the BOLD magnetic field disturbance. In conclusion, the remote vasculature can disturb the BOLD field distribution and consequently influence BOLD signals at the VOI. Due to the radial distant decay and orientation-dependence of the kernel of the magnetic dipole magnetic field and to the arbitrary remote vasculature configuration, the remote vasculature effect on BOLD signal involves many factors. Simulation results show that the remote vasculature at a distance farther than 5mm may be ignorable.

7961-143, Poster Session

Multiresolution voxel decomposition of complex-valued BOLD signals reveals phasor turbulence

Z. Chen, Z. Chen, V. D. Calhoun, The Mind Research Network (United States)

High-resolution functional MRI (fMRI) technology continues to enable smaller voxel sizes, providing details about neuronal activity in terms of spatial localization and biomagnetic field mapping. Blood oxygenation-level-dependent (BOLD) imaging is a widely accepted mechanism for the study of neuroimaging and brain mapping. Based on recent work from our group, we report the presence of phasor turbulence complex-valued BOLD signals (spiraling and entangling of complex-valued signals in polar diagram) under recursive voxel subdivision. Our results show that high resolution BOLD fMRI may produce phasor turbulence which can be explained by the irregular BOLD field disturbance induced by blood oxygenation variation associated with neuronal activity. At high resolution, phasor turbulence happens at the large vessel boundary and around the corner of vessel intersection. The phasor turbulence may be used to refine the neuronal activity localization. However, it also increases the image noise as a result of unstable phasor turbulence. In practice, we should take into consideration the tradeoff between image contrast and noise suppression in the high resolution fMRI pursuit.

7961-144, Poster Session

Simulation of fast wavelet encoded MR image reconstruction with compressed sensing

Z. Liu, S. D. Mitra, B. S. Nutter, Texas Tech Univ. (United States)

Traditional MRI scanners acquire images that are encoded in the spatial frequency domain, known as k-space. Recent developments in Compressed Sensing (CS) provide an efficient means to acquire and reconstruct natural images from a reduced number of linear projection measurements at sub-Nyquist sample rates. CS is well suited to fast acquisition of MRI by sparse encoding. However, the commonly used Fourier-encoded MRI scheme weakly satisfies the incoherent measurement constraint in CS. Wavelet-encoded MR imaging can be reconstructed from a more sparse k-space than can Fourier-encoded MRI at the same resolution and is flexible in selective excitation to yield an encoding scheme similar to the "universal encoding". In this work, a CS-MRI scheme has been investigated to reconstruct MR images from sparsely wavelet-encoded k-space. This sparse encoding is achieved with tailored spatially-selective RF excitation pulses that are designed by Battle-Lemarie wavelet functions. The Fourier transforms of these wavelet functions are smooth and decay to zero rapidly. These functions provide short RF pulses with relatively precise excitation profiles. Simulator results show that the proposed encoding scheme offers superior characteristics from conventional Fourier and Wavelet encoding methods, and could be applied to fast MR image acquisition at relatively high resolution.

7961-145, Poster Session

Modified total variation norm for the maximum a posteriori ordered subsets expectation maximization reconstruction in fan-beam SPECT brain perfusion imaging

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In order to improve the tradeoff between noise and bias and to minimize the partial volume effect in the reconstructed images, we modified conventional TV (L1) norm and replaced it by two independent TV (L1u) norms: TVxy and TVz in 3D reconstruction space. We investigated performance of MAP-OSEM-TV algorithm for reconstruction in fan-beam collimator SPECT regional Cerebral Blood Flow imaging. We found that two hyperparameters were required for fan-beam collimator SPECT reconstruction with modified TV norm and that it produced images with lower bias, slightly higher noise and the same partial volume effect, as compared to conventional TV norm.

7961-146, Poster Session

New method for tuning hyperparameter for the total variation norm in the maximum a posteriori ordered subsets expectation maximization reconstruction in SPECT myocardial perfusion imaging

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In order to improve the tradeoff between noise and bias, and to improve uniformity of the reconstructed myocardium while preserving spatial resolution in parallel-beam collimator SPECT myocardial perfusion imaging (MPI) we investigated the most advantageous approach to provide reliable estimate of the optimal value of hyperparameter for the Total Variation norm in the iterative Bayesian Maximum A Posteriori Ordered Subsets Expectation Maximization (MAP-OSEM) One Step Late (OSL) tomographic reconstruction with Gibbs prior. Our aims were to reach the lowest bias at the lowest noise while maximizing uniformity and spatial resolution for the myocardium. Conventional approach is to use the highest curvature point on the L-curve (log of TV norm vs. log of loglikelihood) to estimate the optimal value of the hyperparameter.

We investigated whether the bias vs. noise curve could provide better approach in this context. We found that the bias-noise curve obtained for the structure of interest (myocardium) was a better method than L-curve for the optimized hyperparameters determination. It provided significantly higher quality of the reconstructed images, as compared to the conventional L-curve method.

7961-147, Poster Session

Effect of de-noising and DDRV correction on cone-beam SPECT reconstruction with non-uniform attenuation

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SPECT (single photon emission computed tomography) is a non-invasive, cost-effective means for assessment of tissue/organ functions in nuclear medicine. For many clinical applications, cone-beam geometry is preferred, which can improve count density and spatial resolution, and quantitative reconstruction of radiotracer distribution inside the body is desired. In our previous research, an efficient, analytical solution to cone-beam SPECT reconstruction was developed that allowed simultaneous compensation for the non-uniform attenuation and distance-dependent resolution variation (DDRV), as well as accurate treatment of Poisson noise. However, we found that there are some interactions among these three corrections, which have the significant effects on the reconstructed images. In this paper, we proposed four analytical reconstruction schemes for cone-beam SPECT. By compared simulation results of all the four reconstruction schemes, we studied the effects of de-noising and DDRV correction on cone-beam SPECT reconstruction with non-uniform attenuation, and noticed that the reconstruction scheme and both can obtain better reconstruction results.

7961-148, Poster Session

Quality controls and optimized segmentation methods for PET/CT gated in a clinical setting

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This study presents quality controls and segmentation tools for gating acquisition imaging of moving tumors.

We study the effect of different motion amplitudes in a bin in function of sizes of spheres and signal to background ratios (SBR). Simple rules are then derived to establish which bins are appropriate to quantify tumor activity and to delineate volume. Finally the threshold technics for gated acquisition exams are discussed in function of the different parameters. Our experimental setup consist of a movable platform, a thorax phantom with 6 fillable spheres and a real time position management device allowing to synchronize the PET/CT image with motion. The spheres were filled with F-Fluoro-2-deoxy-glucose and the activity in the tank was adjusted to obtain SBR ratios from 3.5 to 20 (228 combinations of experimental parameters were studied). Maximal activity, optimal threshold and elongation of the sphere images between static and moving tumors are then compared with our own matlab program. Significant changes appear for motion superior to $7.5~$mm in a bin. These changes lead to an activity decrease, an increase of the optimal threshold and an elongation in the movement direction. These effects are accentuated for low SBR and a sphere diameter inferior to $20~$mm. The optimal threshold value are around $35%$ for high size spheres and high SBR. This value increases when the sphere size and the SBR decrease. We then deduce from our measurements the relevant parameters for the delineation procedure.

In conclusion, the effect of motion are successfully quantified in function of the sphere size, SBR and motion in a bin.

Calibration threshold curves are now available in a clinical routine used for gated acquisitions.

7961-149, Poster Session

Using spherical basis functions on a polar grid for iterative image reconstruction in small animal PET

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Statistical iterative methods have been extensively demonstrated to outperform analytical methods in terms of image quality in nuclear imaging. The mathematically unknown biodistribution is usually represented by cubic basis functions. Alternatively, spherical basis functions have demonstrated the lower noise produced in the resulting reconstructed images. Additionally, the system response matrix (SRM), a key element required by iterative methods, is usually too large not to be stored in memory. The SRM can be calculated prior to reconstruction and stored on-disk, and thus be directly accessed by a regular computer during the reconstruction process. This approach usually makes the process too time consuming. To reduce the number of elements to be computed and stored, a common approach is using the scanner symmetries. In this work we use polar voxels, reducing the number of non-zero elements to be computed by a factor 72, allowing also to speed up the Monte-Carlo simulations in which the computation of the SRM is based. In this work we combine the use blobs as basis functions and a polar representation in the SRM. The latter is especially important for blobs, given that due to the overlapping of blobs, the size of the SRM significantly increases. This work will show a quantitative comparison of reconstructed images using Cartesian voxels, polar voxels and blobs. We will show that blobs reduce image noise compared to voxels, and how this approach affects the spatial resolution. These results will be further compared with using polar voxels combined with post-reconstruction smoothing.

7961-150, Poster Session

Full modeling of AX-PET, a new PET device with axially oriented crystals, based on GEANT4 and GATE

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AX-PET is a novel PET detector based on long axially arranged crystals and orthogonal Wavelength Shifter (WLS) strips, both individually readout by Geiger-mode Avalanche Photo Diodes (G-APD). Its design was conceived in order to reduce the parallax error and simultaneously improve spatial resolution and sensitivity. The sensitivity can be further enhanced by adding additional crystal layers as well as by including Inter-Crystal scatter (ICS) events, identified and processed post-acquisition. AX-PET unique features require dedicated Monte Carlo (MC) simulations and its non conventional design makes its modeling rather challenging. We developed an AX-PET model based on Geant4 and GATE packages. Simulations were extensively validated against experimental data obtained from both small scale laboratory and full module setups. The first ones aimed at developing an analytical model of the WLS behavior which was afterwards coupled to GATE. Full AX-PET acquisitions were used to test the GATE simulations. The agreement between data and simulations was very good. AX-PET simulations are employed to test and optimize image reconstruction software and, at the same time, train ICS identification and reconstruction algorithms.

7961-151, Poster Session

Observing the high-resolution capabilities of a silicon PET insert probe

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A high resolution silicon detector probe in coincidence with a conventional PET scanner should be able to increase the scanner's spacial resolution. The MADEIRA PET probe in coincidence with a clinical scanner was simulated using the Monte Carlo package GATE. The device consists of ten layers of silicon of 1x1x1 mm³ pixels in a 80x52 array. Simulations were run with various activity distributions: a set of four points sources, a derenzo phantom and a low activity cylinder containing two cylinders of different size and activity. No attenuation geometry was included to reduce the amount of scatter in the data. The simulations were done in air. Coincidence sorting was performed on the singles list mode data using a time window of 4.5 sec and an energy window of 400-650 keV in the ring and a probe energy threshold of 20 keV. Random coincidences were rejected and no time or energy blurring was used in order to isolate the events which determine the highest achievable spatial resolution. Sinograms where calculated from the sorted data with one sinogram containing events where both annihilation photons were detected in the PET ring and another for probe-ring events. The probe-ring sinograms identified the limited FOV of the probe. The point-spread function was calculated from the sinograms by taking line profiles through the line traced by a point source. The FWHM decreased from 5.5 mm in the ring-ring sinogram to 2.7 mm in the ring-probe sinogram. The FWTM decreased from 7 mm to 3 mm.

7961-152, Poster Session

Ultrafast image reconstruction of a dual-head PET system by use of CUDA architecture

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Positron emission tomography (PET) is an important imaging modality in both clinical usage and research studies. For small-animal PET imaging, it is of major interest to improve the sensitivity and resolution. We have developed a compact high-sensitivity PET system that consisted of two large-area panel PET detector heads. The highly accurate system response matrix can be computed by use of Monte Carlo simulations, and stored for iterative reconstruction methods. By exploiting the symmetry property in the dual-head system, the computational demands can be dramatically reduced. Nevertheless, the tremendously large system size and repetitive reading of system response matrix from the hard drive will result in extremely long reconstruction times. The implementation of an ordered subset expectation maximization (OSEM) algorithm on a CPU system (four Athlon x64 2.0 GHz PCs) took about 2 days for 1 iteration. Consequently, it is imperative to significantly accelerate the reconstruction process to make it more useful for practical applications. Specifically, the graphic processing unit (GPU), which possesses highly parallel computational architecture of computing units can be exploited to achieve a substantial speedup. In this work, we employed the state-of- art GPU, NVIDIA Tesla C2050 based on the Fermi-generation of the compute united device architecture (CUDA) architecture, to yield a reconstruction process in a timely manner. We will demonstrate that reconstruction times can be drastically reduced by using the GPU. The OSEM reconstruction algorithms will be implemented employing both GPU-based and CPU-based codes, and their computational performance will be quantitatively analyzed and compared.

7961-153, Poster Session

Evaluation of image gating as an approach for noise estimation and optimisation of SPECT images

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Temporal sub-sampling of SPECT projection data approach was introduced and validated using the gating technique to estimate the statistical properties of SPECT reconstructed images. A dynamic planar flood and Jaszczak phantom scans were used to validate the proposed method. In general, the comparison between gating and dynamic planar flood 57Co source scans has shown that a temporal sub-sampling approach is valid. The analysis of the results of the gated planar acquisitions have shown that the distribution of the value of single pixel sampled at different time slots follows a Gaussian distribution and that the pixel values are independent and randomly distributed around the mean pixel values.

The SPECT Jaszczak phantom results shown that this method can be used for accurately estimating the level of random noise in phantom and clinical SPECT studies. It also avoids the problem of pixel value correlation, which is faced when using small ROI in estimating noise in SPECT images. The comparison between the large ROI, small ROI and the gating technique shows good agreement between temporal sampling method and the large ROI analysis. The small ROI analysis has consistently under estimated the noise level in the images.

The results achieved and discussed in this study have illustrated that the estimation of SPECT image noise using the gating technique can be an accurate method of estimating local noise levels in clinical planar and SPECT images. Furthermore, this method can be used for the objective optimisation of clinical imaging protocols and the selection of image reconstruction parameters.

7961-154, Poster Session

Singles-prompt, a novel method to estimate random coincidences by using prompts and singles information

J. F. Oliver, M. Rafecas, Instituto de Física Corpuscular, Univ. de València (Spain)

Random coincidences are one of the main sources of image degradation in Positron Emission Tomography (PET) imaging. This aspect becomes especially important when high image quality is needed or accurate quantitative analysis is undertaken. To correct for these degradation effects, an accurate method to estimate the contribution of random events is necessary. A common method of choice is the so called ``Singles Rate'' method (SR), widely used because of its good statistical properties. SR is based on the measurement of the singles count rate in each detector, Rij= 2 t Si Sj.

However, the SR method always overestimates the correct randoms rate value, especially for non--extended sources close to the field of view (FOV) of the scanner. In this work an extension of the SR method is proposed. The novel method, called ``Singles-Prompts'' (SP) takes advantage of the extra information provided by the measured prompts. %It includes the contributions of true coincidences to the randoms rate and estimate these from knowledge of prompt rates.

Changing SR by SP is straightforward since only two simple replacements in the SR formula are required. To validate the method, Monte Carlo simulations have been performed. A small animal PET has been used together with two limiting source geometries.

The results show that the SP estimation is more accurate than that of SR and always has a smaller variance. More importantly, for energy windows

that prevent to register multiple events caused by inter-crystal scatter (ICS), the SP method estimation is compatible with the correct value regardless of the geometry of the source.

7961-155, Poster Session

An application specific PET prototype with multi-energy resolution detectors

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Designed for general purpose, conventional PET systems are constructed with identical detectors and have fixed performances. However, applications with particular detection objects have various requirements on system performance at different detection areas. It is common to find conventional PET's performance insufficiently low at regions of interests (ROIs) but redundantly high at the others. To handle this problem, we are developing an application specific PET prototype consisting of inhomogeneous detectors to provide adjustable performance at different ROIs. This paper reports investigation on the proposed prototype consisting of two kinds of inhomogeneous detectors with different energy resolution. The higher performance detectors are arranged continuously on the scanner. A liver phantom extracted from CT image is modeled as our object of detection. Different ROIs are set in the model including liver and lesion. For the lesion ROI, various locations with fixed size are considered. The coincidence events of each ROI are analyzed with different distributions of the higher performance detectors. Preliminary results indicate that the proposed prototype obtains higher true count and lower scatter count, resulting in lower scatter fractions in both the ROI and the whole object. The degree of the reduction on scatter fraction is varied with the detector arrangements. In the future work, we will analyze the image quality of all ROIs under different layout of higher performance detectors, and investigate the dependence of such arrangements on the characteristics of ROI.

7961-156, Poster Session

Basic design and simulation of a SPECT microscope for in vivo stem cell imaging

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The state-of-the-art in nuclear medicine imaging has achieved ~250 micron spatial resolution with single-photon tomography (SPECT) and ~1.0 mm resolution with positron emission tomography (PET) in small animal research systems. However, in order to achieve cellular resolution In Vivo clearly an order of magnitude improvement in resolution must be achieved. This project, a Gamma Microscope for imaging stem cells, aims to achieve ~15 microns spatial resolution by incorporating the latest in detector technology, image formation, and image processing technologies. We are utilizing a thin silicon detector from CERN, TIMEPIX. The TIMEPIX package includes the multi-channel, low noise integrated circuitry required to achieve high resolution for low energy x-ray and gamma-ray photon imaging. Photon energy is selected to be sufficiently low to collimate and form images with micro-structures, yet high enough to penetrate millimeters of animal tissue for in vivo imaging. This detector is used in combination with a thin gold foil "coded aperture", a pattern of holes. The coded aperture was made in collaboration with industry specialist and it variance from the ideal will be details. The design is aimed at visualizing radio labeled stem cells in a sparse background, using post acquisition processing algorithms that are common in astronomy applications. Our progress in the development modeling of the gamma microscopy system, with concentration on the coded aperture, image processing, and detector performance parameters will be reported. In addition efforts toward imaging radiolabeled stem cells and reporter-gene techniques will be discussed.

7961-09, Poster Session

K-edge subtraction imaging using energy-resolving pixellated detectors

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K-edge subtraction (KES) imaging is typically implemented at synchrotron sources, where the possibility of tuning the beam energy allows two images to be taken at energies immediately below and immediately above the K-edge of a contrast agent, thus maximising the differences in absorption in regions where the contrast agent is present, and minimising the differences in other regions.

We propose an alternative approach, based on the use of pixellated spectroscopic detectors and of a polychromatic beam from a conventional source, and therefore featuring better accessibility than a synchrotron-based technique.

The spectral information from the detector allows the selection of two energy windows, above the K-edge and below the K-edge, respectively. In this way, the two images required for K-edge subtraction are acquired with a single exposure, removing any artifacts resulting from incorrect image registration and reducing the dose to the patient.

This work presents results obtained with two energy-resolving pixellated detectors (Cadmium Telluride and Cadmium Zinc Telluride with a 250 x 250 μm2 pixel) and a test object filled with iodine-based contrast agent. Data will be presented for different concentrations of contrast agent, statistics and choices of energy windows.

Spectral and dosimetric issues will be discussed. Results so far proved the great potential of energy-resolving KES in terms of image quality and dose reduction.

7961-157, Poster Session

Verification of nonlinearity in digital x-ray images using surrogate method

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The purpose of this study is to investigate the nonlinearity in digital X-ray images as a foundation examination for a noise-content rejection process using a mathematical model, which realizes an accurate digital X-ray image system. We have verified minutely the nonlinearity of the digital X-ray image system by using the method of surrogate and the Wayland test, a type of nonlinear analysis, using some profiles taken in two directions (the direction vertical to the X-ray tube (V-direction) and the direction horizontal to the X-ray tube (H-direction)) extracted in computed radiography (CR) images. In the method of surrogate, we use the Fourier transform surrogate data that preserve the results of the frequency analysis of the original data. The translation error calculated by the Wayland test can be used for evaluating the complexity of the orbit of a signal aggregate called the attractor reconstructed in a high-dimensional phase space. The nonlinearity is determined by statistically comparing the translation error of the original data with that of the surrogate data. X-ray images are obtained to investigate the effects of various tube voltages-50 and 80 kV-and dose settings-2 and 10 mAs. In the H-direction, nonlinearity is found at all settings. On the other hand, nonlinearity is only found at 10 mAs and 80 kV in the V-direction. On the basis of these results, it is indicated that the factors of nonlinearity exhibit a comprehensive variation of pixel values because of the heel effect or the sensitivity nonuniformity of an imaging plate.

7961-158, Poster Session

A software tool for quality assurance of computed radiography (CR) systems

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Recommended methods to test the performance of computed radiography (CR) systems have been established by The American Association of Physicists in Medicine Report No. 93, ``Acceptance Testing and Quality Control of Photostimulable Storage Phosphor Imaging Systems". The quality assurance tests are categorized based on how frequently they need to be performed. Quality assurance of CR systems is the responsibility of the facility that performs the exam and is governed by the state in which the facility is located. For Example, the New York State Department of Health has established a guide which lists the tests that a CR facility must perform for quality assurance. We developed practical and easy to use test objects

7961-159, Poster Session

Validation of a method to convert an image to appear as if acquired using a different digital detector

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We have developed a method to convert digital mammograms acquired on one system to appear as if acquired using another system with a different digital detector. This could be used in studies comparing the clinical efficacy of different systems. The signal transfer properties (STP), modulation transfer function (MTF) and noise power spectra (NPS) were measured for the detectors on two systems: a computed radiography (CR) and a digital radiography (DR) system. The contributions to the NPS from electronic, quantum and structure sources were calculated by fitting a second order polynomial at each spatial frequency across the NPS at each dose. The conversion process involves blurring the original image with the ratio of the MTFs in frequency space. Noise with the correct magnitude and spatial frequency content was added to account for differences in the detector response and changes in dose. The method was tested on 16 images of a CDMAM test object acquired on the two systems with anti-scatter grid at five dose levels. The highest dose images were converted to lower dose images for the same detector, then images from the DR were converted to appear as if acquired at a similar dose on CR. The contrast detail curves derived using the simulated CDMAM images were compared to those from the real images. Excellent correlation between simulated and real CR images can be achieved at typical exposure levels for mammography.

7961-160, Poster Session

Measuring the presampled MTF from a reduced number of flat-field images using the noise response (NR) method

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We evaluate a new method for measuring the presampled modulation transfer function (MTF) using the noise power spectrum (NPS) obtained from a few flat-field images acquired at one exposure level. The NPS is the sum of structure, quantum, and additive instrumentation noise, which are proportional to exposure squared, exposure, and a constant, respectively, with the spatial-frequency dependence of the quantum noise depending partly on the detector MTF. Cascaded linear-systems theory was used to derive an exact and generic relationship that was used to isolate noise terms and enable determination of the MTF directly from the noise response, thereby circumventing the need for precision test objects (slit, edge, etc.) as required by standard techniques. Isolation of the quantum NPS by fitting the total NPS versus exposure obtained using 30 flat-field images each at six or more different exposure levels with a linear regression provides highly accurate MTFs. A subset of these images from indirect digital detectors was used to investigate the accuracy of measuring the MTF from 30 or fewer flat-field images obtained at a single exposure level. Analyzing as few as two images acquired at a single exposure resulted in no observable systematic error. Increasing the number of images analyzed resulted in an increase in accuracy. Fifteen images provided comparable accuracy with the most rigorous slope approach, with less than 5% variability, suggesting additional image acquisitions may be unnecessary. Reducing the number of images acquired for the noise response method further simplifies and facilitates routine MTF measurements.

7961-161, Poster Session

CZT detector in multienergy x-ray imaging with different pixel sizes and pitches: Monte Carlo simulation studies

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The potential of photon counting x-ray imaging based on semiconductor materials is recognized in many fields. Among the semiconductor materials of a wide band gap, the cadmium telluride (CdTe) and cadmium zinc telluride (CZT) have attracted most attention as x-ray detectors. CZT detectors can be operated at room temperature because CZT crystals have a wide band gap. In addition, CZT detectors have high detection efficiency and energy resolution. However, the CZT detectors exhibit several problems with hole trapping and charge sharing. Charge sharing occurs due to diffusion of charge and characteristic x-ray escape and scattered x-rays in the detectors. In this study, we evaluated the effect of the characteristic x-rays in multienergy x-ray imaging with a CZT detector using Monte Carlo simulations. X-ray energy spectrum acquired at 50 kVp tube voltage and 2 mm Al filtration. Geant4 Application for Tomographic Emission (GATE) version 6.0 was used for a CZT crystal with size of 10 10 mm2. The thickness of 1 mm was chosen since it allows >90% absorption efficiency of the photons at 50-kVp. The detector pixel with sizes of 0.09 0.09, 0.45 0.45, and 0.90 0.90 mm2 were simulated. For all pixel sizes, the x-ray spectra of the simulations were distorted towards the lower energy region. Because the characteristic x-rays add counts in the range of 20-40 keV. The magnitude of this deterioration is substantial for small pixel sizes. Correction methods should be developed based on the results.

7961-162, Poster Session

Effect of x-ray incident direction and scintillator layer design on image quality of indirect-conversion flat-panel detector with GOS phosphor

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We characterized the image quality of two types of indirect-conversion flat-panel detectors: the X-ray incident side photo-detection system (IS) and the X-ray penetration side photo-detection system (PS). These detectors consisted of a Gd2O2S:Tb (GOS) scintillator coupled with a Photodiode-Thin Film Transistor (PD-TFT) array on a glass substrate.

These detectors had different X-ray incident directions, glass substrates, and scintillators. We also characterized the effect of layered scintillator structures on image quality using a single-layered scintillator containing large phosphor grains and a double-layered scintillator consisted of a layer containing large phosphor grains and a layer containing small phosphor grains.

The IS system always showed a higher MTF than the PS one when the thickness of the scintillator was the same. Moreover, IS system showed higher DQE than the PS system when a thick scintillator was used. The double-layered scuintillators were useful for improving MTF for both systems, but the thick single-layered scintillator was preferable to obtain high DQE when IS system was applied. These results indicated that the IS system could efficiently utilize the light emitted from phosphor at the far side of the PD without blurring. The use of IS systems makes it possible to increase the thickness of the scintillator layer in order to improve the sensitivity without reducing MTF, which increases the DQE. The DQE of the IS system was 1.2 times that of the PS system despite the absorption of X-rays at the glass substrate before entering the scintillator.

7961-163, Poster Session

Graphical user interface for a dual-module EMCCD x-ray detector array

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A new Graphical User Interface (GUI) was developed using Laboratory Virtual Instrumentation Engineering Workbench (LabVIEW) for a high-resolution, high-sensitivity Solid State X-ray Image Intensifier (SSXII), which is a new x-ray detector for radiographic and fluoroscopic imaging, consisting of an array of Electron-Multiplying CCDs (EMCCDs) each having a variable on-chip electron-multiplication gain of up to 2000x to reduce the effect of readout noise. To enlarge the field-of-view (FOV), each EMCCD sensor is coupled to an x-ray phosphor through a fiberoptic taper. Two EMCCD camera modules are used in our prototype to form a computer-controlled array; however, larger arrays are under development. The new GUI provides patient registration, EMCCD module control, image acquisition, and patient image review. Images from the array are stitched into a 2k×1k pixel image that can be acquired and saved at a rate of 17 Hz (faster with pixel binning). When reviewing the patient's data, the operator can select images from the patient's directory tree listed by the GUI and cycle through the images using a slider bar. Commonly used camera parameters including exposure time, trigger mode, and individual EMCCD gain can be easily adjusted using the GUI. The GUI is designed to accommodate expansion of the EMCCD array to even larger FOVs with more modules. The high-resolution, high-sensitivity EMCCD modular-array SSXII imager with the new user-friendly GUI should enable angiographers and interventionalists to visualize smaller vessels and endovascular devices, helping them to make more accurate diagnoses and to perform more precise image-guided interventions.

7961-164, Poster Session

CMOS image sensor based x-ray detector noise characterization and its fixed pattern noise correction method

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A CMOS image sensor based X-Ray detector has recently been developed for the application of dental practice. The X-Ray detector has an inherited CMOS image sensor fixed pattern noise and other temporal noise. In order to offer a quality image for dental diagnosing, the X-Ray image must be processed and corrected prior to displaying for customer use. The X-Ray detector noise has been studied and characterized. Four X-Ray devices are used in the investigation. Both an X-Ray source and a green visual LED light source are used to determine the magnitude of X-Ray photon shot noise, and two sets of images, a single-flood image and a 20-averaged image, are studied to characterize the photon response non-uniformity noise. The investigation shows that the device has different noise sources, with fixed pattern noise and X-Ray photon shot noise being the dominant noise sources of the device. Separating these noises from each other helps to improve image quality by reducing or even eliminating some noise components. The paper first describes the noise characteristics of the X-Ray detector. It then illustrates the method to separate the column fixed pattern noise from other noise sources. A correction method of the fixed pattern noise is proposed and implemented. The experiments and testing image data demonstrate the effectiveness of the proposed fixed pattern noise correction method.

7961-165, Poster Session

Selenium coated CMOS passive pixel array for medical imaging

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Digital imaging systems for medical applications use amorphous silicon thin-film transistor (TFT) technology due to its ability to be manufactured over large areas, making it useful for X-ray imaging, which requires imagers to be the size of the subject, unlike optical imaging. TFT technology is used to make imaging arrays coated with an X-ray detector called amorphous selenium (a-Se), which can be grown easily over large areas by being evaporated on a substrate. However, TFT technology is far inferior to crystalline silicon CMOS technology in terms of the speed, stability, noise susceptibility, and feature size. Where CMOS technology falls short is its inability to be manufactured in large wafers at a competitive cost, allowing TFT technology to continue to be dominant in the medical imaging field, unlike the optical imaging industry.

This work investigates the feasibility of integrating an imaging array fabricated in CMOS technology with an a-Se detector. The design of a CMOS passive pixel sensor (PPS) array is presented, in addition to how it is integrated with the amorphous selenium detector. Results show that the integrated Selenium-CMOS PPS array has good responsivity to optical light and X-rays, leaving the door open for further research on implementing CMOS imaging architectures going forward. Demonstrating that the PPS chips using CMOS technology can use a-Se as a detector is thus the first step in a promising path of research, which should yield substantial and exciting results for the field. Though area may still prove challenging, larger CMOS wafers can be manufactured and tiled to allow for a large enough size for certain diagnostic imaging applications and potentially even large area applications like digital mammography.

7961-166, Poster Session

CMOS digital intra-oral sensor for x-ray radiography

C. Liu, Fairchild Imaging (United States)

Digital intra-oral x-ray sensor has experienced rapid growth in recent years. The transition from film to digital sensors has resulted in significant dose reduction for the patients and imaging quality improvement for the dentists. Digital intra-oral sensor products today incorporate either CCD or CMOS imaging chips.

In this paper, we present a CMOS digital intra-oral sensor for x-ray radiography. The sensor system consists of a custom CMOS imager, custom scintillator/fiber optics plate, camera timing and digital control electronics, and direct USB communication.

The CMOS imager contains 1700 x 1344 pixels. The pixel size is 19.5um x 19.5um. The imager was fabricated with a 0.18um CMOS imaging process. Since the die size is much larger than the standard lithography reticle size, stitching technology was used in the fabrication. The CMOS

imager design features chamfered corners for patient comfort and a novel x-ray trigger circuit. The pixel design features reduced dark current, enhanced quantum efficiency, variable gain and extended well capacity.

Cesium Iodide (CsI) scintillator was directly deposited on fiber optic plate. The scintillator was optimized for optimal SNR and MTF tradeoff.

All camera functions were integrated within the sensor housing and a standard USB cable was used to directly connect the intra oral sensor to the host computer.

The overall system has a measured x-ray conversion gain of 62DN/uGy, a SNR greater than 160 under 400uGy dose. The sensor demonstrated wide dynamic range from 5uGy to 1300uGy, and the measured peak DQE is 48% over various dose levels.

7961-167, Poster Session

Design and fabrication of single grain (SG) TFTs and lateral PIN photodiodes for low dose x-ray detection

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Patients are exposed to a relatively high amount of X-ray radiation during medical diagnostics and treatment which already carries a risk as a consequence of radiation accumulation in the body. Therefore, to decrease the dose without losing the image quality, X-ray detector performance has to be improved.

Digital X-ray radiography detectors are using a-Si thin-film-transistors (TFT) which require lower process temperature compared to IC technology and hence permit use of large area glass substrates. However, due to the amorphous nature, mobility is very low (1 cm2/ Vs). Poly-Si TFTs improve mobility and enables higher resolution but due to random grain boundaries, defect density is still high [1] and results in image lag.

This paper introduces a novel digital large-area X-ray image sensor based on TFTs and photodiode fabricated in crystalline-Si islands on predetermined 2D-positions [2]. A low-temperature process, based on the µ-Czochralski technique, has been developed in TU Delft and used to control the positions of the islands.

Fabricated NMOS and PMOS SG-TFTs have 600 cm2/Vs and 250 cm2/Vs mobility, respectively. Therefore, the new X-ray image sensor is a solution to the lag problem and frequency limitation of a-Si TFT while achieving a detection area for chest radiography without the tiling process.

Indirect conversion [3] is being used with lateral PIN photodiodes which are fabricated using single grain technique. Photodiodes with 1 um wide intrinsic region are located inside 6 um x 6 um Si-islands and have more than 60% quantum efficiency at 400 nm. The effect of the intrinsic area size will be investigated with different crystalline structures of silicon photodiodes. We will integrate the photodiodes with scintillator and demonstrate X-ray detection performance.

References:

1. A. Kelly, G. W. Groves, and P. Kidd, Crystallography and crystal defects, New York: Wiley 2000.

2. P. C. van der Wilt, B. D. van Dijk, G. J. Bertens, R. Ishihara, and C. I. M. Beenakker, “Formation of location-controlled crystalline islands using substrate-embedded seeds in excimer-laser crystallization of silicon films,” Applied Physics Letters, vol. 72, p. 1819-2001.

3. Jean-Pierre Moy, “Large area X-ray detectors based on amorphous silicon technology,” Thin Solid Films 337 (1999) 213-221.

7961-169, Poster Session

Photon quantum shot noise limited array in amorphous silicon technology for protein crystallography applications

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An array of ring voltage controlled oscillators (RVCO) aiming for photon quantum shot noise limited applications such as protein crystallography is presented. The pixelated array consists of 24 by 21 RVCO pixels. RVCO pixel converts X-ray generated input charge into an output oscillating frequency signal. This architecture can be used in both direct and indirect detection schemes. In this paper the direct detection using a layer of amorphous selenium (a-Se) coupled with the RVCO array is proposed. Theoretical and Experimental results for an in-house fabricated array of RVCOs in amorphous silicon (a-Si) technology are presented. All different requirements for protein crystallography application are listed in this paper and also the way this array addresses each of these requirements is discussed in details in this paper. The off-panel readout circuitry, designed and implemented in-house, is given in this research. The off-panel readout circuit has to be optimized in order to reduce the fixed pattern noise and fringing effects in an imaging array containing many such RVCO pixels. Noise estimations, stability simulations and measurements for some randomly selected pixels in the array for the fabricated RVCO array are presented. The reported architecture is particularly promising for large area photon quantum shot noise applications, specifically protein crystallography. However, this architecture can be used for low dose fluoroscopy, dental computed tomography (CT) and other large area imaging applications limited by input referred electronic noise due to its very low input referred electronic noise, high sensitivity and ease of fabrication in low cost a-Si technology.

7961-170, Poster Session

Study of gain phenomenon in lateral metal-semiconductor-metal detectors for indirect conversion medical imaging

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Previously, metal-semiconductor-metal (MSM) lateral amorphous selenium (a-Se) detectors have been proposed for indirect detector medical imaging applications. These detectors have raised interest due to their high-speed and photogain. The gain measured from these devices was assumed to have been photoconductive gain; however the origin of this gain was not fully understood. In addition, whether or not there was any presence of photocurrent multiplication gain was not investigated. For integration-type applications photocurrent multiplication gain is desirable since the total collected charge may be increased over the total number of absorbed photons. In order to fully appreciate the value of MSM devices and their benefit for different applications, whether it is counting or integration applications, we need to investigate the responsible mechanisms of the observed response. In this paper, we systematically study, through experimental and theoretical means, the nature of the photoresponse and its responsible mechanisms. This study also exposes the possible means to increase the performance of the device and under what conditions it will be most beneficial.

7961-171, Poster Session

Complete erasing of ghost images caused by deeply trapped electrons in computed radiography plates

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The ghost images, i.e., unerasable and reappearing latent images appeared on computed radiography (CR) plates made of europium-doped Ba(Sr)FBr(I) were completely erased by simultaneous exposing them to filtered ultraviolet light and visible light. Three different types of CR plates (Agfa, Kodak, and Fuji) were irradiated with 50 kV X-ray beams in the dose range 8.1 mGy to 8.0 Gy, and then conventionally erased for 2 h with visible light. The remaining unerasable latent images could be erased by repeating 6 h simultaneous exposures to filtered ultraviolet light and visible light. After the sixth round of exposure, all the unerasable latent images in the three types of CR plates were erased to the same level as in an unirradiated plate and no latent images reappeared after storage at 0ºC for 14 days.

The absorption spectra of deep centers in all types of irradiated CR plates were specified by a method similar to that for luminescence excitation spectra, using polychromatic ultraviolet light from a deep-ultraviolet lamp. It was found that deep centers showed a dominant peak in the absorption spectra at around 324 nm for the Agfa and Kodak plates, and at around 320 nm for the Fuji plate, in each case followed by a few small peaks. After completely erasing CR plates, these peaks were no more observed. It was concluded that electrons trapped in deep centers cause unerasable latent images and these electrons can be erased by simultaneous exposure to filtered ultraviolet light and visible light.

7961-172, Poster Session

Energy weighting with a CdTe spectrometric detector

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The technique of energy weighting takes advantage of the energy information of each photon given by spectrometric detectors. It has been shown that energy weighting can lead to improved image quality in terms of contrast to noise ratio (CNR) or significant dose reduction. For low energy photons (< 40 keV), the photoelectric effect is the predominant interaction and E-3 is a good approximation to the optimal weighting function. In our studies, we investigate energy weighting with a CdTe spectrometric detector (linear array of 16 pixels) and a large energy spectrum (100 kV). Measurements are done on a iodinated phantom. We evaluate the evolution of the CNR when using the function Ex and varying x from -4 to 3 for different iodine concentrations. The results show that energy weighting leads to a CNR enhancement > 1.67 compared to the case of energy integrating detectors. The optimal function were found to be E-1 and E0 respectively for high (20 and 10 mg/cm2) and low (2 and 1 mg/cm2) iodine concentrations. Detector response impacts on optimal weighting factors, and hence on CNR according to iodine concentration. We also show that the energy bin size has a relatively small impact on the CNR. Energy weighting with spectrometric detectors seems promising and need further study.

7961-173, Poster Session

Evaluation and comparison of high-resolution (HR) and high-light (HL) phosphors in the micro-angiographic fluoroscope (MAF) using generalized linear systems analyses (GMTF, GDQE) that include the effect of scatter, magnification and detector characteristics

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In this study, we evaluated the imaging characteristics of the high-resolution, high-sensitivity micro-angiographic fluoroscope (MAF) with 35-micron pixel-pitch when used with different commercially-available 300-micron thick phosphors: the high resolution (HR) and high light (HL) from Hamamatsu. The purpose of this evaluation was to see if the HL phosphor with its higher screen efficiency could be replaced with the HR phosphor to achieve improved resolution without an increase in noise resulting from the HR's decreased light-photon yield. We designated the detectors MAF-HR and MAF-HL and compared them with a standard flat panel detector (FPD) (194-micron pixel pitch and 600-micron thick CsI(Tl)). For this comparison, we used the generalized linear-system metrics of GMTF, GNNPS and GDQE which are more realistic measures of total system performance since they include the effect of scattered radiation, focal spot distribution, and geometric un-sharpness. Magnifications (1.05-1.15) and scatter fractions (0.28 and 0.33) characteristic of a standard head phantom were used. The MAF-HR performed significantly better than the MAF-HL at high spatial frequencies. The ratio of GMTF and GDQE of the MAF-HR compared to the MAF-HL at 3(6) cycles/mm was 1.58(1.97) and 1.40(1.97), respectively. Despite significant degradation by inclusion of scatter and object magnification, both MAF-HR and MAF-HL provide superior performance over the FPD at higher spatial frequencies with similar performance up to the FPD's Nyquist frequency of 2.5 cycles/mm. Both substantially higher resolution and improved GDQE can be achieved with the MAF using the HR phosphor instead of the HL phosphor.

7961-174, Poster Session

LBP based detection of intestinal motility in WCE images

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In this research study, a system to support medical diagnosis in the detection of intestinal contractions by processing endoscopic images is presented. Small intestine contractions are among the motility patterns which reveal many gastrointestinal disorders, such as functional dyspepsia, paralytic ileus, irritable bowel syndrome, bacterial overgrowth. The images have been obtained using the Wireless Capsule Endoscopy (WCE) technique, a new form of gastrointestinal endoscopy that is performed with a miniaturized, swallowable camera that is able to trasmit color high-fidelity images of gastrointestinal tract to a portable recording device. Manual annotation of contractions is an elaborating task, since the recording device of the capsule stores about 50,000 images and contractions might represent only the 1% of the whole video.

In this paper we propose the use of Local Binary Pattern (LBP), that provides highly discriminative texture information. It is combined with the powerful textons statistics to find the frames of the video related to contractions.

We report a sensitivity of about 80% and a specificity of about 99%.

We also discuss the effects of various parameters on our classification algorithm such as the choice of filter bank, the size of the texton dictionary as well as the number of training images used. Furthermore we compare the performance of texton classifier with the Support Vector Machine based classifier that uses the same basic features. The achieved high detection accuracy of the proposed system has provided thus an indication that such intelligent schemes could be used as a supplementary diagnostic tool in endoscopy.

7961-175, Poster Session

Temperature anomaly detection and estimation using microwave radiometry and anatomical information

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Many medically significant conditions (e.g., ischemia, carcinoma and inflammation) involve localized anomalies in physiological parameters such as the metabolic and blood perfusion rates. These in turn lead

to deviations from normal tissue temperature patterns. Microwave radiometry is a passive system for sensing the radiation that objects emit naturally in the microwave frequency band. Since the emitted power depends on temperature, and since radiation at low microwave frequencies can propagate through several centimeters of tissue, microwave radiometry has the potential to provide valuable information about subcutaneous anomalies. The radiometric temperature measurement for a tissue region can be modeled as the inner product of the temperature pattern and a weighting function that depends on tissue properties and the radiometer's antenna. In the absence of knowledge of the weighting functions, it can be difficult to extract specific information about tissue temperature patterns (or the underlying physiological parameters) from the measurements. In this paper, we consider a scenario in which microwave radiometry works in conjunction with another imaging modality (e.g., 3D-CT or MRI) that provides detailed anatomical information. This information is used along with sensor properties in electromagnetic simulation software to generate weighting functions. It also is used in bio-heat equations to generate nominal tissue temperature patterns. We then develop a hypothesis testing framework that makes use of the weighting functions and nominal temperature patterns to detect anomalies, and also propose a means for estimating temperature anomalies from the power measurements. Simulation results are presented to illustrate the proposed detection and estimation procedures.

7961-176, Poster Session

Optimization of differential phase-contrast imaging setups using simulative approaches

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Differential phase-contrast imaging with X-ray tubes is influenced by conventional X-ray imaging setups. Parameters, which are optimized for conventional setups, may not be optimal for differential phase-contrast imaging. Therefore, there is a high potential for optimization of differential phase-contrast imaging. Quantities like visibility, contrast to noise ratio, and dose can be combined to form an objective function. For differential phase-contrast imaging those possible objective functions are generally not known analytically and are expected to be non-linear. The optimization of differential phase-contrast is still possible as the quantities, which are necessary to form an objective function, can be obtained by a simulation. Additionally, setup parameters can be varied more purposefully within the simulation than it would be possible in an experimental setup. To take particle as well as wave contributions into account a Monte-Carlo simulation framework and a wavefield simulation framework are used. Numerical optimization procedures using simulation results to obtain the objective function are an adequate approach to find optimal setups for differential phase-contrast imaging. Hence, different optimization procedures are evaluated and compared. Results for an optimized phase grating and an optimized analyzer grating are presented. The appropriate optimization procedure and the optimal setup depend on the intended application of the setup and the constraints which the setup parameters have to obey.

7961-178, Poster Session

SEM and microCT validation for en face OCT imagistic evaluation of endodontically treated human teeth

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The succes of endodontic therapy is based on diagnosis, treatment planning, knowledge of tooth anatomy, endodontic cavity design, controlling the infection by thorough cleaning and shaping, methods and materials used in root canal obturation. An endodontic obturation must be a complete, three dimensional filling of the root canal system, as close as possible to cemento-dentinal junction, without massive overfilling or underfilling.

There are several methods known which are used to assess the quality of the seal, but most of them are invasive. These lead to the destruction of the probes and often no conclusion could be drawn in respect to the existence of any microleakage in the investigated areas of interest. Using an en-face version of OCT, we have recently demonstrated real time thorough evaluation of quality of root canal fillings.

The purpose of this in vitro study was to validate the en face OCT imagistic evaluation of endodontical treated human theeth by using scanning electron microscopy (SEM) and microcomputer tomography (μCT).

SEM investigations evidenced the nonlinear aspect of the interface between the endodontic filling material and the root canal walls and materials defects in some samples.

The results obtained by μCT revealed also some defects inside the root-canal fillings and at the interfaces with the root-canal walls.

The advantages of the OCT method consist in non-invasiveness and high resolution. En face OCT investigations permit to visualize a more complex stratificated structure at the interface filling material/dental hard tissue and in the apical region.

7961-179, Poster Session

Performance evaluation of a differential phase-contrast cone-beam CT (DPC-CBCT) system for soft tissue imaging

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Differential phase-contrast (DPC) technique is promising as the next breakthrough in X-ray imaging and CT field. Utilizing the long ignored X-ray phase information, DPC has the potential to provide us with projection images of higher contrast in a CT scan leading to a more real reconstruction of the scanned object. In order to validate and investigate the DPC technique, a new DPC-based cone-beam computed tomography (DPC-CBCT) system has been designed and constructed in our lab for soft tissue imaging. The DPC-CBCT system consists of a micro-focus x-ray tube (focal spot 8 μm), a high-resolution detector, a rotating phantom holder and two gratings, i.e. a phase grating and an analysis. The detector system has a phosphor screen, an optical fiber coupling unit and a CMOS chip with an effective pixel pitch of 22.5 microns. The optical elements are aligned to minimize unexpected moiré patterns, and system parameters, including tube voltage (or equivalently x-ray spectrum), distances between gratings, source-to-object distance and object-to-detector distance are optimized. The system is tested with phantoms and tissue samples (vascular or breast tissue). 3-D volumetric phase-coefficients are reconstructed, which are considerably larger (theoretically 1000 times) than the linear attenuation coefficient. The total exposure level is equivalent to a conventional CBCT scan of small animals with the spatial resolution of the reconstruction in about 20 microns.

7961-180, Poster Session

X-ray tube-based phase CT: spectrum polychromatics and imaging performance

X. Tang, Y. Yang, S. Tang, Emory Univ. (United States)

Owing to its advantages in differentiating low-atomic materials over the conventional attenuation-based CT, the x-ray tube-based phase CT implemented with grating interferometers has increasingly drawn attention. Via the Talbot-effect, the phase variation of an object is

retrieved and reconstructed to characterize the object's x-ray refractive property. Since the Talbot-effect is wavelength dependent, the spectrum polychromatics of an x-ray tube blurs the interference fringe, which may degrade the imaging performance of x-ray tube-based phase CT significantly. In this work, to provide guidelines for architecture design and optimization, we quantitatively investigate into the imaging performance of x-ray tube-based phase CT over peak voltages (kVp) through system modeling, computer simulation and experimental evaluation and verification, with a focus on the influence of x-ray source spectrum polychromatics on system spatial resolution and required x-ray dose for reliable phase retrieving. We'll also investigate into the optimization of imaging performance by narrowing the x-ray source spectrum via various beam filtration techniques. It is believed that the outcome of this work will be of practical significance to establish x-ray tube-based phase CT as an imaging modality with the imaging performance substantially exceeding that has been achieved by the conventional attenuation-based x-ray CT.

7961-181, Poster Session

X-ray phase computed tomography for nanoparticulated imaging probes and therapeutics: preliminary feasibility study

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With the scientific progresses in cancer biology, pharmacology and biomedical engineering, nano-biotechnology based imaging probes and therapeutical agents (namely probes/agents) - a form of theranostics - has become one of the promising strategies for the cure of cancer. The key feature distinguishing the nanoparticulated probes/agents from their conventional counterparts is their targeting capability. A large surface-to-volume ratio in nanoparticulated probes/agents enables the accommodation of multiple targeting, imaging and therapeutic agents to cope with the intra- and inter-tumor heterogeneity. Most nanoparticulated probes/agents are synthesized with low atomic number materials. Thus, comparing to biological tissues, their x-ray attenuation are very similar. However, their microscopic structures are very different, which may result in significant differences in their refractive behaviors. Recently, the investigation in x-ray phase CT has demonstrated its advantages in differentiating low-atomic number materials over conventional attenuation-based CT. We believe that a synergy of x-ray tube-based phase CT and nanoparticulated imaging probes and therapeutics will play a significant role in extensive preclinical and clinical applications, and even hopeful become a modality for molecular imaging. Hence, we propose to image the refractive, either single or multiple, or both, property of nanoparticulated imaging probes and therapeutical agents with x-ray tube-based phase CT in this work. We conduct a preliminary feasibility study with quantitative data to provide practical guidelines for the architecture design and performance optimization of x-ray tube-based phase CT, which may facilitate the translation of preclinical research findings in the nanomedicine-based theranostics into clinical applications.

7961-182, Poster Session

A new technology for terahertz imaging in breast cancer margin determination

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In this paper we describe a project for designing, developing and translating a THz imaging device for monitoring margins from extracted tissue during surgical breast cancer conservation procedures. In this application, the reflective and transmission properties of extracted tissue is monitored, in near real-time using a fine-beam THz signal which is sensitive to the presence of liquid and bound water content. In this way, it is intended that the extracted tissue will be studied in the operating theatre to determine during surgery, whether or not the region of malignant tissue has been fully excised from the patient. In the early stages of this project, we are determining to what degree an existing THz system at the University of Massachusetts (UMass) in Amherst is able to differentiate between breast carcinoma, and normal fibroglandular and adipose tissues. This will be achieved through a close collaboration with a surgical and radiological team at the UMass-Worcester medical school and will involve post-surgical recovered tissues. As part of this work, we will be describing the system, the measurement methodology, and first results that will be obtained to calibrate the basic system.

7961-183, Poster Session

Retaining axial-lateral orthogonality in steered ultrasound data to improve image quality in reconstructed lateral displacement data

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Ultrasound elastography tracks tissue displacements under small levels of compression to obtain images of strain, a mechanical property useful in the detection and characterisation of pathology. Due to the nature of ultrasound beamforming, only tissue displacements in the direction of beam propagation, referred to as 'axial', are measured to high quality, although an ability to measure other components of tissue displacement is desired to more fully characterise the mechanical behaviour of tissue. Previous studies have used one-dimensional (1D) 'angular' axial displacements tracked from steered ultrasound beams to reconstruct improved quality displacements across the scan plane ('lateral'). Two-dimensional (2D) displacement tracking is not possible with steered ultrasound data; a method of reshaping frames of steered ultrasound data to retain axial-lateral orthogonality, which permits 2D displacement tracking, is presented. Simulated and experimental ultrasound data are used to compare changes in image quality of lateral displacements reconstructed using 1D and 2D tracked angular axial, and angular lateral, data. Reconstructed lateral displacement image quality generally improves with 2D displacement tracking, particularly at high levels of compression. Unsteered lateral displacements and reconstructions using angular lateral displacements have better RMSE values than axial-based reconstructions at high levels of applied strain.

7961-184, Poster Session

Simulation of ultrasound backscatter images from fish

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The objective of this work is to investigate ultrasound (US) backscatter in the MHz range from fish to develop a realistic and reliable simulation model. The long term objective of the work is to develop the signal processing needed for fish species differentiation using US. In in-vitro experiments, a cod (Gadus morhua) was scanned with a BK Medical ProFocus 2202 ultrasound scanner as well as a Toshiba Aquilion ONE CT scanner. The center frequency of the transducer is 10 MHz. The Full Width at Half Maximum (FWHM) of the point spread function (PSF) at (the) focus point is 0.54 mm in the lateral direction. The measured US images of the fish were compared with US images simulated using the ultrasound simulation program Field II. The transducer model in Field II

was calibrated using a wire phantom to check the point spread function. The inputs to the simulation were Computed Tomography image data of the same fish to create simulated scatter maps. The positions of the point scatterers were assumed to be uniformly distributed. (The) scatter amplitudes were generated with a new method based on the segmented CT data in Hounsfield Units and backscatter data for the different tissues from the literature. The simulated US images represent most of the measured US image characteristics.

7961-185, Poster Session

New method to test the gantry rotation angle of a linear accelerator used in radiation therapy

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The precision of a medical LINear ACcelerator (LINAC) gantry rotation angle is crucial for the radiation therapy process, especially in stereotactic radio surgery and in Image Guided Radiation Therapy (IGRT) where the mechanical stability is disturbed due to the additional weight of the kV x-ray tube and detector.

We present in this paper an extension of the Winston and Lutz test1 initially dedicated to control the size and the position of the isocenter of the LINAC and here adapted to test the gantry rotation angle with no additional portal images. This new method uses a test-object patented by QualiFormeD and is integrated in QUALIMAGIQ software platform developed to analyze automatically images acquired for medical devices quality controls.

7961-186, Poster Session

Calculation of conversion factors between human and automatic read-out of CDMAM images

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According to the 'European protocol for the quality control of the physical and technical aspects of mammography screening' (EPQC) image quality of digital mammography units has to be evaluated using the CDMAM (contrast-detail mammography) phantom.

The evaluation of image quality is accomplished by the determination of threshold thicknesses of gold disks of different diameters (0.08 mm to 2 mm). This task has to be performed by qualified human observers and revealed to be very time consuming.

Another drawback of this method is the high variance of the results which leads to the demand of many observers to get more reliable numbers. Therefore a software solution was provided by the Euref group known as 'cdcom'. The problem with this program is that it provides data different from the results gained by human readers.

Factors for the conversion from automatic to human read outs depend on the diameter of the gold disk and were estimated using a huge amount of data, both human and automatic read outs. But these factors provided by various groups differ from each other and are purely phenomenological. Our approach uses the Rose theory to calculate the results of the threshold thicknesses theoretically. Therefore we can calculate the factor based on theory which reveals to be very robust and produces factor more or less equal to the phenomenological ones.

7961-187, Poster Session

Image noise sensitivity of dual-energy digital mammography for calcification imaging

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Dual-energy digital mammography (DEDM) can suppress the contrast between adipose and glandular tissues and generate dual-energy (DE) calcification signals. DE calcification signals are always influenced by many factors. Image noise is one of these factors. In this paper, the sensitivity of DE calcification signal to image noise was analyzed based on DEDM physical model. Image noise levels of two different commercially available digital mammography systems, GE Senographe Essential system and GE Senographe DS system, were measured. The mean noise was about 1.04% for Senographe Essential system, 1.42% for Senographe DS system at 28kVp/50mAs; and was 0.47% for Senographe Essential system, 0.79% for Senographe DS system at 48kVp/12.5mAs. Evaluations were performed by comparing RMS (Root-Mean-Square) of calcification signal fluctuations in background regions and CNR (Contrast-Noise-Ratio) of calcification signals in clusters when these two digital mammography systems were used. The results showed that image noise sensitivities of DE calcification signals were very high. Image noise had a serious impact on DEDM calcification signals. If GE Senographe Essential system was used, calcification signal fluctuations were 200~300μm, and when calcification size is greater than 300μm, the probability of acquiring CNR≥3 is over 50%. If noise reduction techniques are used, the calcification threshold size of CNR≥3 can be lower.

7961-188, Poster Session

Abnormal breast tissue imaging based on multi-energy x-ray

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In screening mammography, tissue contrast may be degraded due to overlapping of normal and abnormal tissues. The contrast can be improved in tissue-selective images that are reconstructed from multi-energy images, based on the difference of energy dependency of x-ray attenuation between tissues. To obtain an abnormal tissue image, three material decomposition should be made possible, since normal breast mainly consists of adipose and glandular tissues. However, it generally requires exact knowledge of breast thickness and x-ray attenuation coefficients of materials. In this work, we propose a method to generate an abnormal tissue image from multi-energy x-ray image, without prior knowledge. We show that abnormal tissue can be revealed from the breast thickness map that is reconstructed via basis material decomposition (BMD). Note that BMD process needs the attenuation coefficients of basis materials, the actual attenuation coefficient, however, varies according to breast density of the patient. Hence we parameterize the attenuation curve with density parameters and search the parameters that maximize the uniformity of breast thickness. Breast thickness is computed by addition of thickness maps of glandular and adipose tissues. Here, thickness maps of glandular and adipose tissues are obtained via polynomial regression between multi-energy x-ray image and weighted thickness maps of the calibration phantom. It is proved via simulation that the proposed method improves the detection of mass that is hidden by other overlapping normal tissues.

7961-189, Poster Session

High contrast soft tissue imaging based on multi-energy x-ray

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Overlapping fibroglandular tissue structures in a breast may obscure mass and microcalcifications, essential to the early detection of breast cancer. In this paper, we propose a method to generate the high contrast mammogram with distinctive features of a breast cancer by using the multiple images obtained with different x-ray spectra. On the experimental results of the breast specimen images, the proposed method provides a noticeable image quality with obvious mass structure and microcalification.

7961-190, Poster Session

Detailed characterization of 2D and 3D scatter-to-primary ratios of various breast geometries using a dedicated CT mammotomography system

J. Shah, J. H. Pachon, P. Madhav, M. P. Tornai, Duke Univ. (United States)

Using a dedicated breast CT system with a quasi-monochromatic x-ray source and flat-panel digital detector, the 2D and 3D scatter to primary ratios (SPR) of various geometric phantoms having different densities were characterized. Projections were acquired using two geometric and anthropomorphic breast phantoms. Each phantom was filled with 700ml of 5 different water-methanol concentrations to simulate effective boundary densities of breast compositions from 100% glandular to 100% fat. Each condition was imaged with and without added acrylic yarn to mimic internal connective tissue. Projections were acquired with and without a beam stop array. For each projection, 2D scatter was determined by cubic spline interpolating the values behind the shadow of each beam stop through the object. Scatter-corrected projections were obtained by subtracting the scatter, and the 2D SPRs were obtained as a ratio of the scatter to scatter-corrected projections. Additionally the (un)corrected data were individually iteratively reconstructed. The (un)corrected 3D volumes were subsequently subtracted, and the 3D SPRs obtained from the ratio of the scatter volume-to-scatter-corrected (or primary) volume. Results show that the 2D SPR values peak in the center of the volumes, and were overall highest for the simulated 100% glandular composition. Consequently, scatter corrected reconstructions have visibly reduced cupping regardless of the 'breast' geometry, as well as more accurate attenuation coefficients. Not surprisingly, the corresponding 3D SPRs have increased central density, which reduces radially. Overall, these results indicate the need for scatter correction for different geometries and breast densities with 3D cone beam breast CT.

7961-191, Poster Session

Characterization of image quality for 3D scatter corrected breast CT images

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A dedicated breast CT system with a quasi-monochromatic x-ray source and flat-panel digital detector has been constructed for uncompressed breast imaging. The goal of this study was to characterize the image quality of our system under scatter corrected and non scatter corrected conditions for a variety of breast compositions. CT projections were acquired of a breast phantom containing sets of acrylic 'lesions' at two radial distances, that varied in size (2-8mm) based on their polar position. The breast phantom was filled with 3 different concentrations of methanol and water, simulating a variety of breast densities; acrylic yarn was sometimes included to simulate connective tissue of a breast. For each phantom condition, 2D scatter was estimated by cubic spline interpolating the average values behind the shadow of each beam stop inside the object measured for various projection angles. Scatter-corrected and uncorrected projections were then reconstructed with an iterative algorithm. Reconstructed image quality was characterized using SNR and contrast analysis, and followed by observer studies to detect and qualitatively rate the lesions on the different concentric rings. Results show that scatter correction effectively reduces the cupping artifact and improves image contrast and SNR. These findings indicate that applying dedicated scatter correction for differing breast conditions improves image quality.

7961-192, Poster Session

Evaluation of image quality in computed radiography based mammography

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Mammography is the most widely accepted procedure for the early detection of breast cancer and Computed Radiography (CR) is a cost-effective technology for digital mammography. The purpose of this research was to determine if the CR mammography image quality is acceptable for Digital Mammography. The image quality of mammograms acquired using Computed Radiography was evaluated using the Modulation Transfer Function (MTF), Noise Power Spectrum (NPS) and Detective Quantum Efficiency (DQE). The measurements were made using a 28 kVp beam (RQA M-II) using 2 mm of Al as a filter and a target/filter combination of Mo/Mo. The acquired image bit depth was 16 bits and the pixel pitch for scanning was 50 µm. A Step-Wedge phantom was used to measure the Contrast-to-noise ratio (CNR) and the CDMAM 3.4 Contrast Detail phantom was used used to assess the fine detail contrast. The CNR values were observed at varying thickness of PMMA. A detail thickness vs. diameter curve was plotted using the CDMAM 3.4 phantom and compared to the EUREF acceptable and achievable values. The detector response function was also plotted for the system. The effect on image quality was measured using these physics metrics. A lower DQE was observed compared to the DQE observed using flat-panel detectors (FPDs). This could be possibly due to a higher noise component present due to the way the scanner was configured. The CDMAM phantom scores demonstrated a contrast-detail comparable to the EUREF values. A cost-effective CR machine was optimized for high-resolution and high-contrast imaging.

7961-193, Poster Session

Quality assurance (QA) tool for computed radiography mammography (CRM) systems

A. Singh, iCRco, Inc. (United States)

Quality Assurance (QA) is a key component of mammography imaging. QA should ensure that all the components of the x-ray imaging chain are working properly to enable the acquisition of a high-quality mammogram. We developed a computer-based, procedure driven protocol for Quality Assurance that enables a facility to implement an effective QA program for CR Mammography. The Mammo QA tool is a Java-based application that includes an explanation of proper QA procedures to enable the physicist, technologist and the radiologist to verify the correct functioning of the x-ray imaging chain. For a physicist, the tool describes the x-ray system calibration including x-ray components such as the Automatic Exposure Control (AEC), Grid movement, Compression Paddle and Optimal beam quality. For the technologist, the tool describes proper positioning of the breast, correct exposure techniques, proper collimation, QC tests for checking the spatial and contrast resolution of the system and evaluation of mammography phantom images. It provides the radiologist essential tips to assess image quality issues. The digital implementation of this tool can be delivered online or via a CD/DVD.

It can be tailored to specific mammography systems and can also be integrated with existing digital Quality Control (QC) work stations. Poor image quality can lead to incorrect diagnosis. This software tool includes all the procedures of the x-ray imaging chain for acquiring a high-quality mammogram. It will also facilitate the collection of QA data and provide QA reports.

7961-194, Poster Session

Quality evaluation of different technologies for mammograms digitizers

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Taking into account requirements for processing digital mammograms, systems dealing with the optimization of images acquisition need to be adequately evaluated. The processes for generating these images are varied and they can be grouped mainly in two categories: (1) films scanned by specialized digitizers; (2) images obtained from electronic sensors associated to digital converters (CR and DR systems). The main two types of different scanners are those with white light-based detection and CCD sensors and with a scanning laser beam. Thus the current investigation aims to perform quality evaluation of film digitizers, mainly addressed to mammography. In this analysis the following parameters were studied: digitizers characteristic curves - relating the pixel value assigned to a region and the corresponding optical density of the film on the same region; noise - obtained by the Wiener spectrum; and reproducibility - evaluating whether a device used to capture a digital image can be reliable in subsequent scans. Six different digitizer equipments were investigated with purposes of determining tools to enhance the image quality based on their characteristics. The results have indicated that although the most sophisticated scanners have the best characteristics among those evaluated, knowledge about the scanner behavior can allow developing procedures to provide the adequate quality image for processing schemes.

7961-195, Poster Session

Evaluation of the quality of image for various breast composition and exposure conditions in digital mammography

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The breast density has a close relation to breast cancer risk. The exposure parameter must be chosen for each breast appropriately. However, the optimal exposure conditions for digital mammography are uncertain in clinical. We need to optimize the exposure parameter in digital mammography with maximization of the image quality and minimization of patient dose. We evaluated the quality of images for different exposure conditions to investigate the most advantageous tube voltage. For different compressed breast phantom thickness and its composition, we measured the Wiener spectrum (WS), the noise equivalent number of quanta (NEQ) and detective quantum efficiency (DQE). In this study, the signal-to-noise ratios were derived from the perceived statistical decision theory model with the internal noise of eye-brain system (SNRi), contrived and studied by Loo LN, Ishida M and et al. Both were calculated under a fixed average glandular dose (AGD). The WS values obtained with a fixed image contrast. For 50% glandular breast phantom, the result of NEQ showed that high voltages gave superior noise property of images especially for thick breast but the improvement of the NEQ by tube voltage was not so remarkable. On the other hand, the SNRi value with Mo filter was larger than that with Rh filter. The SNRi increased when the tube voltage decreased. The result differs from that of WS and that of NEQ. In this study, the SNRi depends on the contrast of signal. We should make accuracy high with the low contrast object that has intensity

7961-196, Poster Session

Design and validation of a mathematical breast phantom for contrast-enhanced digital mammography

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In contrast-enhanced digital mammography (CEDM) an iodinated contrast agent is employed to increase lesion contrast and to provide tissue functional information. Here, we present the details of a software phantom that can be used as a tool for the simulation of CEDM images, and compare the degree of anatomic noise present in images simulated using the phantom to that in breast parenchyma in clinical CEDM images. Such a phantom could be useful for multiparametric investigations including characterization of CEDM imaging performance and system optimization. The phantom has a realistic mammographic appearance based on a clustered lumpy background and models contrast agent uptake according to breast tissue physiology. Fifty unique phantoms were generated and used to simulate regions of interest (ROI) of pre-contrast images and logarithmically subtracted CEDM images using monoenergetic ray tracing. Power law exponents, 'beta', were used as a measure of anatomic noise and were determined using a linear least-squares fit to log-log plots of the square of the modulus of radially averaged image power spectra versus spatial frequency. The power spectra of ROI selected from regions of normal parenchyma in 10 pairs of clinical CEDM pre-contrast and subtracted images were also measured for comparison with the simulated images. There was good agreement between the measured beta in the simulated CEDM images and the clinical images. The values of beta were consistently lower for the logarithmically subtracted CEDM images compared to the pre-contrast images, indicating that the subtraction process reduced anatomical noise.

7961-197, Poster Session

Automatic patient motion detection in digital breast tomosynthesis

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Patient motion is frequently a problem in mammography, especially when the x-ray exposure is long, resulting in image quality degradation. At present, patient motion can only be identified by inspecting the image subjectively after image acquisition. As digital breast tomosynthesis (DBT) takes longer time to complete each acquisition scan than conventional mammography, there is more chance for patient motion in DBT. Therefore it is important to understand the potential motion problem in DBT and incorporate a design to minimize it.

In this paper we present an automatic method to detect patient motions in DBT. The method is developed based on an understanding that, features of breast should move along predictable trajectory in a time-series of projection measurements; deviations from it are linked to patient motion. Motion distance is estimated by analyzing skin lines and large calcifications (if exist) in all projection images and then a motion score is derived for a DBT scan. Effectiveness and robustness of this method will be demonstrated with clinical data, together with discussions on different motion patterns observed clinically.

The impacts of this work could be far-reaching. It allows real-time detection and objective evaluation of patient motions, applicable to all breasts. Patient with severe motion can be re-scanned immediately before leaving the room. Data with moderate motions can go through additional targeted image processing to minimize motion artifacts. It also enables a powerful tool to evaluate and optimize different DBT designs to minimize the patient motion problem. Besides, this method can be extended to other imaging modalities, e.g. breast CT, to study patient motions.

7961-198, Poster Session

A human observer study for evaluation and optimization of reconstruction methods in breast tomosynthesis using clinical cases

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In breast tomosynthesis (BT) a number of 2D projection images are acquired from different angles along a limited arc. The imaged breast volume is reconstructed from the projection images, providing 3D information. The purpose of the study was to investigate and optimize different reconstruction methods for BT in terms of image quality using human observers viewing clinical cases. Cases with suspected masses and calcifications were collected from 60 patients.

Four different reconstructions of each image set were evaluated by five experienced observers: filtered back projection (FBP), iterative adapted FBP (iFBP) and two ML-convex iterative algorithm (MLCI) reconstructions (8 and 10 iterations) that differed in noise level and contrast of clinical details. Representation of micro calcifications, masses and glandular tissue was evaluated. The structures were rated according to the overall appearance in a relative visual grading (VGA) study where the observers rated the reconstructions in a side-by-side comparison relative to the FBP reconstruction.

Additionally, a rank-order study was performed on the same reconstructions. The observers were forced to rank the order of the different reconstructed images, and their proportions at each rank were scored.

In both FBP and iFBP methods the sharp borders and mass spiculations were better represented than in iterative reconstruction while the out-of-plane artifacts were better suppressed in the latter. However in a clinical practical consensus the differences among these reconstructions were considered negligible.

7961-199, Poster Session

Segmentation of adipose and glandular tissue for breast tomosynthesis imaging

C. M. Shafer, V. L. Seewaldt, J. Y. Lo, Duke Univ. (United States)

Breast tomosynthesis involves a restricted number of images acquired in an arc in conventional mammography projection geometry. Despite its angular undersampling, tomosynthesis projections are reconstructed into a volume at a dose comparable to mammography. Tomosynthesis thus provides depth information, which is especially beneficial to patients with dense breasts. Because the device can be based on an existing FFDM unit, tomosynthesis may be used to accurately assess breast tissue composition, which would greatly benefit high-risk patients with less access to costly imaging modalities such as MRI. This study plans to extract quantitative 3D breast tissue density information using a fully automatic probabilistic model trained on segmented MRIs. The MRI ground truth was obtained for 310 breasts by iterative threshold-based fatty / glandular tissue segmentation. After training a 3D hidden Markov model (HMM) on 10 MR volumes, our model was validated by segmenting 156 of the 310 breasts. After the tomosynthesis histogram correction, the same trained HMM was tested to segment breast tomosynthesis volumes of subjects whose MRIs were used for validation. Initial training / testing of the HMM on MRIs matched density to thresholding within 5% for 62/156 breasts and 10% for 104/156 breasts. HMM segmentation was qualitatively superior at the cranial/caudal end slices in MRIs and quantitatively superior for most tested tomosynthesis volumes. Its robustness and ease of modification give the HMM great promise and potential for expansion in this multi-modality study.

7961-200, Poster Session

Stationary digital breast tomosynthesis with distributed field emission x-ray tube

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Tomosynthesis imaging devices acquire 2D projection images from different viewing angles and reconstruct a 3D data set from the individual projection images. Using comparable doses to 2D mammography, tomosynthesis allows resolving overlapping tissue structures and has the potential for improved diagnostic accuracy. The conventional systems that are now becoming commercially available use a single moving x-ray source on a rotating arm. For a fast scanning time a high moving speed of the arm is desired. While this reduces the motion artifacts from patient motion it leads to a blur of the moving x-ray tube focal spot that limits the achievable spatial resolution. Stationary systems will not suffer from this limitation and have the potential to reduce the scanning time while maintaining or improving the spatial resolution. In this paper we present the design of a tomosynthesis imaging device with a dedicated stationary X-ray tube. The X-ray tube consists of 31 field emission X-ray sources with an angular range of 30°. The field emission electron emitters have the advantage that they do not need any heating circuits compared to thermionic cathodes and that the source to source switching can be controlled very well with a dedicated switching circuit. The total dose is up to 100mAs with an energy range between 27 and 50 kVp. The total scan time will be 4s. Critical for a fast scanning speed is a fast detector with high detective quantum efficiency. Results from focal spot and MTF measurements will be presented. The field emission sources have also undergone extensive lifetime testing.

7961-201, Poster Session

The use of detectability indices as a means of automatic exposure control for a digital mammography system

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This work examines the use of a detectability index to control an Automatic Exposure Control (AEC) system for an amorphous-Selenium digital mammography detector. The default AEC mode for the system was evaluated using homogenous poly(methyl methacrylate) (PMMA) plates of thickness 20, 40, 60 and 70 mm to find the tube potential and anode/filter settings selected by the system for these thicknesses. Detectability index (d') using a non-prewhitened model observer with eye filter (NPWE) was then calculated for these beam quality settings as a function of air kerma at the detector. X-ray beam contrast was included from the measured contrast for a 0.2 mm thick Al square. AEC settings were calculated that gave constant d' as a function of beam quality; a target d' was used that ensured the system passed the achievable image quality criterion for the 0.1 mm diameter disc in the European Guidelines. Detectability in terms of threshold gold thickness was measured using the CDMAM test object as a function of beam quality for the default AEC mode, which held pixel value (PV) constant, and for the constant d' mode. Threshold gold thickness for the 0.1 mm disc was found to increase by a factor of 2 for the constant PV mode, while the constant d' mode held threshold gold thickness constant to within 7%. The constant d' mode also held signal-difference-to noise ratio constant to within 5%.

7961-202, Poster Session

Investigating the potential for super-resolution in digital breast tomosynthesis

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Digital breast tomosynthesis (DBT) is an emerging 3D x-ray imaging modality in which tomographic sections of the breast are generated from a limited range of tube angles. Because non-normal x-ray incidence causes the image of an object to be translated in sub-pixel increments with increasing projection angle, it is demonstrated in this work that DBT is capable of super-resolution (i.e., sub-pixel resolution). The feasibility of super-resolution is shown with a commercial DBT system using a bar pattern phantom. In addition, a framework for investigating super-resolution analytically is proposed by calculating the reconstruction profile for a sine input whose frequency is greater than the alias frequency of the detector. To study the frequency spectrum of the reconstruction, its continuous Fourier transform is also calculated. It is shown that the central projection cannot properly resolve frequencies higher than the alias frequency of the detector. Instead, the central projection represents a high frequency signal as if it were a lower frequency signal. The Fourier transform of the central projection is maximized at this lower frequency and has considerable spectral leakage as evidence of aliasing. By contrast, simple backprojection can be used to image high frequencies properly. The Fourier transform of simple backprojection is correctly maximized at the input frequency. Adding filters to the simple backprojection reconstruction smoothens pixilation artifacts, and reduces spectral leakage found in the frequency spectrum. In conclusion, this work demonstrates the feasibility of super-resolution in DBT experimentally and provides a framework for characterizing its presence analytically.

7961-203, Poster Session

Near-infrared tomography for detection of breast tumor using boundary element method: phantom validation

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The purpose of this paper is to detection of tumor depth in breast phantom using boundary element method (BEM). The paper contains two sections, first section is about the mathematics relations to solve diffusion equation by BEM, and second section consist of experimental data to tumor detection by near-infrared optical tomography. In this study, by optical image reconstruction, the depth of tumor inside phantoms is detected.

One of the most important subjects in optical tomography is to develop a model to study propagation of laser light in the biological tissue. Such modeling helps to calculate intensity of transmitted or reflected light from the tissue. Radiative Transport Equation (RTE) is generally used for light propagation in the biological tissue. If the tissue is highly scattering, RTE can be simplified to Diffusion Equation.In special cases, analytic solutions for DA exist, but the precision of results depends on distance between source and observation point. For more accurate study numerical methods are to be used. Finite Element Method (FEM) and Finite Difference Method (FDM) have been introduced for numerical studies of diffusion equation. In FEM and FDM methods, the volume of sample is discretized; therefore they are time consuming. Moreover, accuracy of FDM method depends on number of nodes. To enhance accuracy, the size of each mesh should decrease those results to longer running time.

Monte Carlo method is an additional method which frequently used to model light transport in turbid media. In this method, large number of photons is traced in the sample until they are absorbed inside the sample or transmitted from it; that is time consuming. Therefore Monte Carlo method is time consuming, but it is generally used for simulation of light-tissue interaction.

Boundary Element method (BEM) is a numerical method that has been widely used in engineering problems to solve partial differential equations. The surface discretization of sample is the most advantage of BEM over other methods.

The purpose of this paper is to solve diffusion equation by BEM. At first diffusion equation is transformed to integral equation by using Green's function. The resulting integral is solved over surface of the sample. The fluence on each internal node can be obtained after calculating fluence on the boundary. In this study, distributions of diffused fluence versus depth in biological phantom like breast tissues are calculated by BEM, Monte Carlo and FDM then the results are compared with each other. We have also calculated the variation of fluence versus depth for breast tissue by means of BEM and the results are compared with those obtained by experimental method. at the end the depth of tumors are investigated by BEM.

7961-204, Poster Session

An approach of long-view tomosynthesis in peripheral arterial angiographic examinations

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Tomosynthesis (TS) has been evaluated as a useful diagnostic imaging tool for the orthopedic market and lung cancer screening. Previously, to expand the reconstructed region of TS, we proposed Long-View Tomosynthesis (LVTS) by using a different acquisition motion and new post-processing algorithms. The LVTS method consists of three steps. First, it acquires multiple images while the X-ray tube and Flat Panel Detector (FPD) are moving in the same linear direction simultaneously. Second, each image is divided into fixed length strips. The strips from different images having similar X-ray beam trajectory angles are then stitched together. Last, multi slice coronal images are reconstructed by utilizing the Filtered Back Projection (FBP) technique from the long stitched images. As a result, LTVS has 432[mm] x 800[mm] image size at maximum and 1.6lp/mm spatial resolution. However, the present LVTS method needs images acquired by the fixed speed motion to stitch each strip precisely. It is necessary to improve this stitching algorithm to apply more clinical examinations. In this paper, we propose utilizing the new LVTS method for bolus chasing angiography that usually acquired at arbitrary variable speeds. We added the method of detecting the moved distance of frames along with anatomical structure and the method of selecting pixel values with contrast media to the stitching algorithm. As a result, LVTS can extract new clinical information like 3-D structure from images already acquired by routine bolus chasing technique.

7961-205, Poster Session

Accurate joint space quantification in knee osteoarthritis: a digital x-ray tomosynthesis phantom study

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The current imaging standard for diagnosis and monitoring of knee osteoarthritis (OA) is projection radiography. However radiographs may be insensitive to markers of early disease such as osteophytes and joint space narrowing (JSN). Relative to standard radiography, digital X-ray tomosynthesis (DTS) may provide improved visualization of the markers of knee OA without the interference of superimposed anatomy. DTS utilizes a series of low-dose projection images over an arc of ±20 degrees to reconstruct tomographic images parallel to the detector. We propose that DTS can increase accuracy and precision in JSN quantification. The geometric accuracy of DTS was characterized by quantifying joint space width (JSW) as a function of knee flexion and position using physical and anthropomorphic phantoms.

Using a commercially available digital X-ray system, projection and DTS images were acquired for a Lucite rod phantom with known gaps at various source-object-distances, and angles of flexion. Gap width, representative of JSW, was measured using a validated algorithm.

Over an object-to-detector-distance range of 5-21cm, a 3.0mm gap width was reproducibly measured in the DTS images, independent of magnification. A simulated 0.50mm (±0.13) JSN was quantified accurately (95% CI 0.44-0.56mm) in the DTS images. Angling the rods to represent knee flexion, the minimum gap could be precisely determined from the DTS images and was independent of flexion angle.

JSN quantification using DTS was insensitive to distance from patient barrier and flexion angle. Potential exists for the optimization of DTS for accurate radiographic quantification of knee OA independent of patient positioning.

7961-206, Poster Session

Image performance evaluation of a 3D surgical imaging platform

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The O-arm (Medtronic Inc.) is a multi-dimensional surgical imaging platform that is optimized and marketed for use in spine and orthopedic surgeries. It provides fluoroscopic (2D) and three-dimensional (3D) imaging capability during surgery, using a large field-of-view flat-panel detector mounted on an O-shaped gantry. The purpose of this study was to perform a quantitative evaluation of the imaging performance of the O-arm in an effort to understand its potential for future non-orthopedic applications. Performance of the reconstructed 3D images was evaluated, using a custom-built phantom, in terms of resolution, linearity, uniformity and geometrical accuracy. Both the standard (SD, 13 sec) and high definition (HD, 26 sec) modes were evaluated, with the imaging parameters set to image the head (120 kVp, 125 mAs and 150 mAs, respectively). For quantitative noise characterization, the images were converted to Hounsfield units (HU) off-line. Measurement of the modulation transfer function revealed a limiting resolution (10%) of 1.15 mm-1 in the axial dimension. Image noise varied between ±16 and 25 HU for the HD and SD modes, respectively. Image intensities varied linearly with over the measured range, up to 1200 HU. Geometric accuracy was maintained in all three dimensions over the field of view. The present study has evaluated the performance characteristics of the O-arm, and demonstrates feasibility for use in interventional applications and quantitative imaging tasks outside those currently targeted by the manufacturer. However, improvements to the reconstruction algorithms may be required to enhance performance for lower-contrast applications.

7961-207, Poster Session

Feasibility study of low-dose intra-operative cone-beam CT for image-guided surgery

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Cone-beam CT has been increasingly used in image-guided surgery as a tool for intra-operative navigation and verification. Currently, CBCT images are reconstructed from projection data that are acquired at hundreds of angular views, and each scan involves a non-negligible amount of radiation exposure to the patient. In this work, we applied the ASD-POCS algorithm to reconstruct CBCT images from projection data that are substantially less than required by current algorithms. We model the CBCT imaging as a discrete linear system, and formulate the reconstruction task as an optimization problem in which one minimizes the image total-variation while enforcing data constraint. To account for inconsistency from various physical factors, we relax the data constraint by a data-error parameter. We generated simulation data and collected real phantom and patient data in a number of imaging configurations with different scanning parameters, including exposure level at each view, total number of projections, and degree of data truncation. We reconstructed images using the ASD-POCS algorithm and other algorithms such as FDK and EM. By cross-comparing among the images obtained with different algorithms and by checking against the ground truth or selected reference images, we performed qualitative and quantitative evaluation of our results. Preliminary findings indicate that the quality of images reconstructed by use of the ASD-POCS algorithm is comparable to that of the ground truth image or the reference image, while involving a fraction of the X-ray exposure required by current algorithms. This technique is potentially useful for low-dose intra-operative CBCT imaging in surgical procedures.

7961-208, Poster Session

Examination of the dental cone-beam CT equipped with flat-panel-detector (FPD)

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In dentistry, computed tomography (CT) is essential for diagnosis. Recently cone-beam CT has come to be used. Moreover, the detector changed from image intensifier (I.I.) to flat-panel detector (FPD), so image quality became better. We evaluated the image qualities of a cone-beam CT equipped with FPD. The system can get kinetic images and CT images. For the functional diagnosis of temporomandibular joint or swallowing, kinetic image is necessary. If the kinetic images and CT images from this system are useful in the clinical site, it brings great benefit for dentistry. In this study, we examined the image quality of kinetic images and CT images. To evaluate the quality of kinetic images we calculated NPSs and MTFs. Then analyzed the lag images and exposed the phantom. To evaluate the quality of CT images we calculated NPSs and MTFs and compared them to the other CT system. From the result of evaluation of kinetic images, it is good enough for the diagnosis in the clinical site. But the effect of the lag images is not negligible. So, if the subject moves quickly it affect to the sharpness of the kinetic image. From the result of CT images, CT images of this system showed better image quality than the other one's. But in exposure of CT images, the gap from the center influences the image quality. So it is necessary to note the positioning.

7961-209, Poster Session

Four-dimensional volume-of-interest reconstruction for cone-beam computerized tomography based image-guided radiation therapy of the lung

M. U. Ahmad, T. Pan, The Univ. of Texas M.D. Anderson Cancer Ctr. (United States)

In image-guided radiation therapy of moving lung lesions, four-dimensional cone-beam CT (4D-CBCT) can be used to produce time-resolved images for tracking the target throughout the breathing cycle. The requirements in 4D-CBCT are short scan time and image quality sufficient to localize the target. Short scans are desirable but result in image-distorting streak artifacts in 4D-CBCT reconstruction. Motion-averaged (also called conventional or 3D) CBCT reconstruction does not suffer from streak artifacts, but lacks the temporal resolution to depict the tumor breathing motion. We define a new composite four-dimensional volume-of-interest (4D-VOI) reconstruction which combines the features of pure 4D and motion-averaged reconstruction image sets. A 4D reconstruction is performed inside of a VOI which contains the moving tumor, and the higher quality motion-averaged reconstruction is performed outside of the VOI. The three image sets (motion-averaged, 4D, and 4D-VOI) are compared. The 4D-VOI image has both low streak artifact and good temporal resolution. The 3D image has very few streak artifacts but lacks the temporal resolution to depict moving structures. On the other hand, the 4D image without VOI processing is severely distorted by streak artifacts. The streak artifacts distort the bony anatomy which is commonly used for patient setup. The advantage of the new 4D-VOI images is that both the moving tumor and the bony anatomy can be used for patient setup and target localization. Although streak

artifacts are commonplace in 4D-CBCT with short scan times, they can be reduced using the 4D-VOI reconstruction method.

7961-210, Poster Session

4D cone beam CT phase sorting using high resolution optical surface measurement during image guided radiotherapy

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In image guided radiotherapy (IGRT), two of the most promising recent developments are four dimensional cone beam CT (4D CBCT) and dynamic optical metrology of patient surfaces. 4D CBCT is now becoming commercially available and finds use in treatment planning and verification, and whilst optical monitoring is a young technology, its ability to measure during treatment delivery without dose consequences has led to its uptake in many institutes. In this paper, we demonstrate the use of dynamic patient surfaces, simultaneously captured during CBCT acquisition using an optical sensor, to phase sort projection images for 4D CBCT volume reconstruction.

The dual modality approach we describe means that in addition to 4D volumetric data, the system provides correlated wide field measurements of the patient's skin surface with high spatial and temporal resolution. As well as the value of such complementary data in verification and motion analysis studies, it introduces flexibility into the acquisition of the signal required for phase sorting. The specific technique used may be varied according to individual patient circumstances and the imaging target. We give details of three different methods of obtaining a suitable signal from the optical surfaces: simply following the motion of triangulation spots used to calibrate the surfaces' absolute height; monitoring the surface height in a single, arbitrarily selected, camera pixel; and tracking, in three dimensions, the movement of a surface feature. In addition to describing the system and methodology, we present initial results from a case study oesophageal cancer patient.

7961-211, Poster Session

Optimization of four-dimensional cone-beam computed tomography in image-guided radiation therapy of the lung

M. U. Ahmad, T. Pan, The Univ. of Texas M.D. Anderson Cancer Ctr. (United States)

In image-guided radiation therapy of moving lung lesions, four-dimensional CBCT (4D-CBCT) can produce several images of the target through the breathing cycle with good temporal resolution. The requirements in 4D-CBCT are short scan time and image quality sufficient to localize the target. Short scans are desirable but result in image-distorting streak artifacts. We have optimized 4D-CBCT by determining the minimum scan time for adequate image quality. We scanned 4 patients with long scan times (3.8 - 5.4 minutes) to produce high-quality oversampled data sets. These serve as the gold standard for image quality assessment. Various shorter scan times were simulated via removal of projection data from the long scans. The projection data were removed in such a way as to maintain an accurate number of total breaths for the various simulated scan times. The amount of global streak artifact and the tumor and bony anatomy shape is assessed for each image set. The original long scans display no major streak artifacts. The moving structures show no sign of motion blurring and have high contrast boundaries. As the scan time is reduced, more global streak artifact appears, originating particularly from the bony anatomy. At a scan time of 2 minutes, there is a moderate level of streak artifact, but the shape of the tumor and bony structures is not compromised. There is some sign of jaggedness in the body outline, ribs, and vertebrae. At 1 minute or less, the streak artifacts severely distort the bony anatomy and may compromise localization.

7961-212, Poster Session

Comparing image quality and radiation dose between new generation MDCT and CBCT systems

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The use of Cone Beam Computed Tomography (CBCT) for in-room image guided interventions has gained more and more popularity over the last decade. In this study, we compiled a low dose Multi Detector Computed Tomography (MDCT) protocol for abdominal imaging and compared this in terms of image quality and radiation dose with a CBCT system. Both systems used in this study are latest generation, so both offer high radiation dose efficiency. To compile the MDCT protocol and to determine the dose distribution of both systems, a Rando-Alderson-Phantom in combination with 25 thermoluminescence dosimeters (TLDs) were used. The equivalent dose for the imaged regions was calculated after ICRP. To determine the image quality of the reconstructed slices, the Catphan600 phantom was used. In terms of quality we determined the spatial resolution, contrast-to-noise ratio (CNR), integral uniformity, and visual inspection. The dose could be reduced by 40% when using our MDCT protocol (120kV 50mAs) compared to the CBCT system (89kV 153mAs). CNR and uniformity are improved for the MDCT, in some cases CNR up to 80%. However, the spatial resolution of the CBCT system was superior, even after reconstructing the MDCT data with a small field-of-view and a relatively hard filter. Visually, the MDCT reconstructions are of higher diagnostic quality. In conclusion, the MDCT provides better dose efficiency in relation to the image quality. However, in cases such as the chemoembolisation, for example, the CBCT system is more convenient because of the possibility to be used during interventions.

7961-213, Poster Session

A comparison of methods for measurement of the line spread function of a CT imaging system

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A quantitative description of the deterministic properties of a CT system is necessary when comparing different imaging systems. The most common metric is the modulation transfer function (MTF), usually calculated from a line spread function (LSF) or point spread function (PSF). Currently, there exist many test objects used to measure the LSF or PSF. In this paper we report a comparison of these methods. We test three techniques: a thin slit test object, a teflon edge test object and a novel "negative" test object. We used the FDA bench-top flat-panel-based cone-beam CT scanner and a cylindrical water-filled PMMA phantom with the test objects embedded in the middle. From the 3-dimensional reconstructed volumes, we measured the LSF either directly or as estimated from the edge response function. From these measurements, a modulation transfer function can be estimated.

7961-214, Poster Session

Performance evaluation of a sub-millimeter spectrally resolved CT system on pediatric imaging tasks

M. M. Yveborg, Royal Institute of Technology (Sweden)

We use cascaded systems analysis applied to a model of our spectrally resolved computed tomography system under development. We show that while the improvement in pixel SDNR for this silicon micro strip system is pushed down by Compton interactions, resulting at a performance at par with energy integrating systems, the small pixel size of only 0.2 mm2 will result in an MTF that is higher at higher spatial frequencies than that of an ideal energy integrating systems a pixel size of 1 mm2. For certain imaging tasks encountered in pediatric imaging, this will result in large improvements in detectability index d´ at any given dose delivered to the infant.

We show the magnitude of these improvements to different imaging task and infant sizes, and also show how operating points (kVp) should be selected to keep the dose as low as reasonable achievable.

7961-215, Poster Session

Characteristics of noise and resolution on image reconstruction in cone-beam computed tomography

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The cone-beam computed tomography (CBCT) is a useful medical imaging modality due to the properties of fast volume coverage, lower radiation dose, easy hardware implementation, and higher spatial resolution. Recently, attention is being paid to address the noise and resolution relationship for CBCT. In CBCT system, image noise and spatial resolution play an important role in image quality. However, there has not been done many works for evaluating the relationship of image noise and the spatial resolution in CBCT. In this study, we evaluated the image noise and spatial resolution as a function of filter, number of projections, and voxel size on reconstructed images in CBCT. The simulated projection data of Catphan 600 phantom were reconstructed using the FDK algorithm. To evaluate the image noise and spatial resolution, the coefficient of variation (COV) of the attenuation coefficient and the modulation transfer function (MTF) in axial images were calculated, respectively. The filters used for reconstruction were Ram-lak, Shepp-logan, Cosine, Hamming, and Hann. A number of projections were 161, 321, 481 and 642 acquired from scanning of 360 degree and the voxels with sizes of 0.10 mm, 0.15 mm, 0.20 mm, 0.25 mm and 0.30 mm were used. The image noise given by Hann filter was the lowest and decreased as functions of number of projections and voxel size. The spatial resolution given by Ram-lak filter was the highest and increased as a function of number of projections, decreased as a function of voxel size. The results of this study show the relationship of image noise and spatial resolution in CBCT and the characteristics of reconstruction factors for trade-off between the image noise and spatial resolution. It can also provide image noise and spatial resolution information for adaptive image quality in the future.

7961-216, Poster Session

Investigation of the effect of varying scatter-to-primary ratios on nodule contrast in chest tomosynthesis

A. Svalkvist, Göteborg Univ. (Sweden); G. Ullman, Uppsala Univ. (Sweden) and Linköping Univ. (Sweden); M. E. Håkansson, Sahlgrenska Univ. Hospital (Sweden); D. R. Dance, Royal Surrey County Hospital (United Kingdom) and Univ. of Surrey (United Kingdom); M. P. Sandborg, G. Alm Carlsson, Linköping Univ. (Sweden); M. Båth, Sahlgrenska Univ. Hospital (Sweden) and Göteborg Univ. (Sweden)

The aim of the present work was to analyze the effects of varying scatter-to-primary ratios on the appearance of simulated structures in tomosynthesis section images. Monte Carlo simulations of the chest tomosynthesis system GE Definium 8000 VolumeRAD (GE Healthcare, Chalfont St. Giles, UK) were used to investigate the variation of scatter-to-primary ratios between different angular projections. The simulations were based on a voxel phantom created from CT images of an anthropomorphic chest phantom, using threshold segmentation with a step density function. An artificial nodule was inserted into 100 different locations of the simulated phantom images, using four different approaches for the scatter-to-primary ratios used in the insertion process. One approach included individual determination of the scatter-to primary-ratio for each projection image and nodule location, while the other three approaches included determination of the mean and median scatter-to-primary ratios for all projection images at each nodule location as well as the scatter-to-primary ratio corresponding to the mean contrast reduction for all projection images at each nodule location. Preliminary results indicate that the scatter-to-primary ratio varies both between the different projection images and between different regions of the lung. It could therefore be beneficial to use an individual scatter-to-primary ratio for each projection image and nodule location when simulating nodules into chest tomosynthesis images in order to obtain a more realistic appearance of the simulated structures.

7961-217, Poster Session

3D lesions insertion in digital breast tomosynthesis images

M. S. Vaz, Barco, Inc. (United States); Q. J. A. Besnehard, C. Marchessoux, Barco N.V. (Belgium)

Digital mammography (DM) is the current standard protocol for breast cancer screening and has significant impact on reducing breast cancer mortality. Still, there persists a need for screening methods with better sensitivity and specificity, which has given rise to volumetric imaging modalities for breast cancer screening such as digital breast tomosynthesis (DBT), breast CT and breast MR. Of these, DBT may be the easiest to adopt because it can be accomplished by retrofitting already deployed DM acquisition systems. A barrier to critically evaluating any new modality, including DBT, is the lack of patient data from which statistically significant conclusions can be drawn: such studies would require large numbers of images from both diseased and healthy patients. To answer this challenge, we propose a method to insert 3D lesions in the DBT images of healthy patients, such that the resulting images appear qualitatively faithful to the modality. Considering the entire breast cancer screening population, the number of detected lesions is low; considering the risk of radiation dose of the modality and that DBT is still not prolific, the need for the proposed method to critically evaluate or to improve the modality and its use is apparent. The proposed method facilitates direct control over all necessary parameters including the lesion placement location and the resulting lesion intensity/contrast. The method works regardless of the reconstruction algorithm used to reconstruct the DBT images.

7961-218, Poster Session

Assessment of image quality from patient anatomical images

Y. Lin, E. Samei, Duke Univ. (United States); X. Wang, J. W. Sehnert, Carestream Health, Inc. (United States); J. T. Dobbins III, Duke Univ. (United States); D. H. Foos, L. L. Barski, Carestream Health, Inc. (United States)

We conducted an experiment to verify a proposed multi-frequency image quality assessment method to quantify radiographic image quality for real-time quality assurance purposes. Three CIRS ATOM series phantoms (1-year old, 5-year old, and 30-year old) were imaged with a Kodak CR system by using 24 unique exposure settings (kVps, mAs, and grid combinations). The exposures were varied from E/4, E/2, E, to 2E, where E was determined by Automatic Exposure Control technique (AEC); two kVps were chosen, i.e., 80kVp and 120kVp; phantoms were also imaged with 8:1 grid, 12:1 grid and without grid separately. The manubrium sterni and lung were chosen as the ROIs to assess the overall image quality of the clinical images. The relative noise and contrast values were evaluated in different sub-bands according to their frequency properties, and signal-difference-to-noise ratio (SDNR) was calculated as a metric to measure image quality. The SDNR were then compared to the subjective ratings of the same ROI established by human observers. Our findings indicated that relative noise evaluated in high frequency sub-bands correlated well with quantum noise. The scattering radiation had little effect on noise calculation, but significantly decreased the estimated contrast in low frequency sub-bands. Multi-frequency image quality assessment method was employed to reveal the relationship between SDNR and other exposure setting combinations. The results were in good agreement with human observers' subjective ratings.

7961-219, Poster Session

A new iodinated liver phantom for the quantitative evaluation of advanced CT acquisition and reconstruction techniques

B. Chen, D. Marin, E. Samei, Duke Univ. (United States)

An iodinated liver phantom is needed for liver CT related studies, such as the quantification of lesion contrast. Prior studies employed water phantom with cylinder-filled iodine solution, which did not reflect real liver anatomy and was difficult to operate. To develop a dedicated liver phantom with anthropomorphic structures and solid lesions, we designed a phantom based on the 22nd slab of ATOM phantom, and included iodinated liver inserts with lesions of different sizes, contrasts, and locations. The concentration of iodine in liver parenchyma was determined according to the HU of clinical images. The concentrations in high and low contrast lesions were selected so as to provide challenging but reasonable detection tasks. The application of the liver phantom was initially validated with three CT protocols. To our knowledge, this is the first anthropomorphic iodinated liver phantom with solid lesions of various sizes and contrasts.

7961-84, Session 16

Definitions and outlook

D. Regulla, Helmholtz Zentrum München GmbH (Germany)

No abstract available

7961-85, Session 16

Biological effects of low-level of radiation: cancer

C. Land, National Cancer Institute, NIH (United States)

Ionizing radiation is a known and well-quantified risk factor for human cancer, based on an extensive literature of epidemiological studies of exposed populations, and of experimental studies at the animal, cellular, and molecular levels. For statistical power reasons, estimates of excess risk are more secure at high compared to low dose levels, but epidemiological studies of the Life Span Study cohort of atomic bomb survivors exposed to acute, whole-body gamma radiation support the existence of excess cancer risks at doses at least as low as 100-200 mGy, depending upon organ site, and studies of patient populations exposed to multiple fluoroscopic examinations during treatment for tuberculosis or scoliosis suggest that each low-dose fraction contributes to cancer risk. Experimental studies indicate that a single secondary electron track induced by a photon interaction with a water molecule within a cell can produce complex damage to a DNA strand for which cellular mechanisms of DNA repair are error-prone, and that some cells with misrepaired DNA lesions are capable of escaping damage response pathways and propagating. This finding suggests that the existence of a low-dose threshold for carcinogenesis is unlikely. The historical controversy concerning low-dose linearity vs. low-dose thresholds has been with us for at least 50 years, when Ed Lewis and Austin Brues argued the matter in connection with cancer risks from nuclear bomb test fallout. I will conclude with a quantitative uncertainty analysis illustration using different assumptions about the probability of a low-dose threshold.

7961-86, Session 16

How do we measure dose and estimate risk?

C. Hoeschen, Helmholtz Zentrum München GmbH (Germany)

No abstract available

7961-87, Session 16

The accuracy of estimated organ doses from Monte Carlo CT simulations using cylindrical regions of interest within organs

M. Khatonabadi, J. Sandberg, Univ. of California, Los Angeles (United States); N. Eshghi, Heinrich-Heine-Univ. Düsseldorf (Germany); J. J. DeMarco, Univ. of California, Los Angeles (United States); E. Angel, Toshiba America Medical Systems, Inc. (United States); A. C. Turner, D. Zhang, C. H. Cagnon, M. F. McNitt-Gray, Univ. of California, Los Angeles (United States)

The purpose of this study was to compare differences in Monte Carlo simulation based organ dose estimates obtained using cylindrical ROIs to those obtained with full organ segmentations.

Full segmentation and placement of ROIs at the approximate volumetric centroid of liver, kidneys and spleen were done for ten patient models. For liver and spleen ROIs with 2cm diameter were placed on 5 consecutive slices, for the left and right kidney 1cm ROIs were used. Voxelized models were generated for use in Monte Carlo simulations. Fixed tube current and tube current modulated (TCM) simulations were performed.

For the fixed current, doses simulated using ROIs differ from those simulated using full segmentations from 11.0% to -27.9% for liver with a RMS difference of 10.1%, from 4.3% to -15.9% for spleen with a RMS of 8.3%, from 11.4% to -21.8% for left kidney with a RMS of 12.9%, and from 36.9% to -25.3% for right kidney with a RMS of 15.9%. In the TCM simulations the RMS differences for liver and spleen were almost twice those seen in the fixed current, whereas for left and right kidney these were similar.

Full body segmentations need expertise and are time consuming. Instead using ROIs would simplify this task and make large scale creation of patient models feasible for estimating patient dose. It was shown that dose calculations using ROIs are comparable to those using full segmentations. For the fixed current simulations the maximum RMS value was 15.9% and for the TCM it was 19.6%.

7961-88, Session 16

An algorithm for intelligent sorting of CT-related dose parameters

T. S. Cook, The Univ. of Pennsylvania Health System (United States); S. L. Zimmerman, The Johns Hopkins Univ. (United States); S. Steingal, W. Boonn, W. Kim, The Univ. of Pennsylvania Health System (United States)

Imaging centers nationwide are seeking innovative means to record and monitor CT-related radiation dose in light of multiple instances of patient over-exposure to medical radiation. As a solution, we have developed RADIANCE--Radiation Dose Intelligent Analytics for CT Examinations, an automated pipeline for extraction, archival and reporting of CT-related dose parameters. Estimation of whole-body effective dose from CT dose-length product (DLP)--an indirect estimate of radiation dose--requires anatomy-specific conversion factors that cannot be applied to total DLP, but instead necessitate individual anatomy-based DLPs. However, a challenge exists because the total DLP reported on a dose sheet often includes multiple separate examinations (e.g., chest CT followed by abdominopelvic CT) or multiple scans through the same anatomy (e.g., triple-phase liver CT). Furthermore, the individual reported series DLPs may not be clearly or consistently labeled. For example, “Arterial” could refer to the arterial phase of the triple liver CT or the arterial phase of a CT angiogram. To address this problem, we have designed an intelligent algorithm to parse dose sheets for multi-series CT examinations and correctly separate the total DLP into its anatomic components. The algorithm uses information from the departmental radiology information system (RIS) to determine how many distinct CT examinations were concurrently performed. Then, it matches the number of distinct accession numbers to the series that were acquired, and anatomically matches individual series DLPs to their appropriate CT examinations. This algorithm allows for more accurate dose analytics and outlier identification, and ultimately improves radiology patient care.

7961-89, Session 17

Evidence-based optimization of image quality/dose in CT

E. Samei, Duke Univ. (United States)

Since its introduction, Computed Tomography has continued to provide a unique advantage in diagnosing and monitoring various diseases. The utility of CT has expanded its use in recent years making it one of the most common imaging examinations performed in developed countries. With this increase utilization, concerns have been raised with respect to increased dose to the population, specially considering the introduction of advanced CT techniques that involve increased dose. Furthermore, the exact level of radiation dose in CT has never been closely monitored and scrutinized. As a result, reducing CT dose has emerged as a universal goal to strive for. Such a task should ideally be done in a measured way such that diagnostic quality is not compromised. However, balancing image quality and radiation dose has proven to be a challenging and complex task. This presentation provides an evidence-based strategy towards optimizing CT imaging. In particular, the focus will be on findings based on Monte Carlo and observer models that can inform a strategy to optimize CT protocols from a scientific standpoint.

7961-90, Session 17

Clinical optimization of protocols

D. D. Cody, The Univ. of Texas M.D. Anderson Cancer Ctr. (United States)

No abstract available

7961-91, Session 17

Dose reduction using prior image constrained compressed sensing (DR-PICCS)

J. Tang, G. Chen, Univ. of Wisconsin-Madison (United States)

A technique for dose reduction using prior image constrained compressed sensing (DR-PICCS) in computed tomography (CT) was proposed in this work. In DR-PICCS, the standard FBP reconstructed images were low-pass filtered and used as the prior image in PICCS reconstruction. Then the prior image and the original projection data were used together by the PICCS algorithm to obtain a low noise DR-PICCS reconstruction, which maintains the spatial resolution of the original projection data. The spatial resolution loss of DR-PICCS was studied using a Catphan phantom by MTF measurement. The noise reduction factor, CT number change and noise texture change were studied using human subject data consisting of 20 CT colonography exams performed under an IRB-approved protocol. In each human subject study, six ROIs (two soft tissue, two colonic air columns, and two subcutaneous fat) were selected for the CT number and noise measurements study. Skewness and kurtosis were used as figures of merit to describe the noise texture. A Bland-Altman analysis was performed to study the agreements of the CT number and noise texture. The results showed that, compared with FBP reconstructions, the MTF curve shows very little change in DR-PICCS reconstructions, spatial resolution loss is less than 0.1 lp/cm, and the noise standard deviation can be reduced by a factor of 3 with DR-PICCS. The CT numbers ,skewnesses and kurtosises in FBP and DR-PICCS reconstructions agree very well, which indicates that DR-PICCS does not change CT numbers and noise textures.

7961-92, Session 17

A clinical comparison study of a novel statistical iterative- and filtered-backprojection reconstruction

P. B. Noel, A. A. Fingerle, B. C. Renger, Technische Univ. München (Germany); L. Goshen, Philips Medical Systems Technologies Ltd. (Israel); D. K. Müller, Philips GmbH (Germany); E. J. Rummeny, M. Dobritz, Technische Univ. München (Germany)

The conventional filtered backprojection (FBP) algorithm employed in reduced dose MDCT acquisitions provides low reconstruction quality, e.g. high noise level, and many artifacts. Thus, there is the need for efficient reconstruction methods that have dose reduction potential while providing high reconstruction quality. In this work we present a comparison study between a statistical iterative reconstruction algorithm called iDose and the FBP algorithm. iDose is a hybrid iterative reconstruction algorithm which provides enhanced image quality while reducing the radiation dose compared to conventional algorithms. We report on the performance of the two algorithms with respect to uniformity, noise characteristics, spatial resolution, and patient studies. With respect to the uniformity of the Hounsfield Units (HU), we found that the mean HU value remains stable while employing iDose. With iDose the noise is significantly reduced. This is reflected by an improvement in the contrast-to-noise ratio and in the noise-power-spectrum compared to the FBP. The measurements of the modulation-transfer-function confirm that with iDose there is no decline in spatial resolution. In clinical studies, slices reconstructed with the iDose algorithm showed significantly lower mean noise. Inspired by our phantom and clinical results, we come to the conclusion that iDose is an important tool when considering the reduction of radiation dose in CT. However, continuous efforts to reduce radiation dose should be further proceeded.

Conference 7962: Image Processing

Monday-Wednesday 14-16 February 2011 • Part of Proceedings of SPIE Vol. 7962
Medical Imaging 2011: Image Processing

7962-01, Session 1

Medical image analysis: today's expectations and tomorrow's challenges

M. Sonka, The Univ. of Iowa (United States)

This presentation will discuss possible future directions of biomedical image analysis. After a brief overview of the current state of the art, recent accomplishments, and current expectations, the focus will be on the future needs of the field. The presentation will discuss both the motivation and medically-oriented demands that will likely shape up the medical image analysis area in the years to come. Examples from application areas that are currently under development and thus likely to find their roles in the clinical reality of tomorrow will be given special attention. Hypotheses will be developed describing possible long-term directions of the field.

7962-02, Session 1

Comparison of fuzzy connectedness and graph cut segmentation algorithms

K. C. Ciesielski, West Virginia Univ. (United States) and The Univ. of Pennsylvania (United States); J. K. Udupa, The Univ. of Pennsylvania (United States); A. X. Falcão, P. A. V. Miranda, Univ. Estadual de Campinas (Brazil)

The main subject of this work is a theoretical and experimental comparison of two popular image segmentation algorithms: fuzzy connectedness FC and graph cut GC. On the theoretical side, our emphasis is on describing a common framework in which both of these methods can be naturally expressed. We give a full analysis of the framework and describe precisely a place which each of the two methods occupies in it. Within the same framework, other region based segmentation methods, e.g., watershed and some versions of level set algorithms can also be expressed. A special emphasis is given to delineation algorithms (i.e., segmentation algorithms returning only one object), since this makes the comparison clearer and since GC works well only in such a set-up. The main distinguishing characteristics of these methods are also analyzed theoretically.

An experimental comparison of the performance of FC and GC algorithms is also included. This concentrates on comparing the running times of actual (as opposed to provable worst scenario) algorithms, as well as on the influence of the output depending on the choice of seed points specified. Some distinguishing characteristics of these algorithms analyzed theoretically are verified and illustrated empirically in the experiments.

7962-03, Session 1

Automated multimodality concurrent classification for segmenting vessels in 3D spectral OCT and color fundus images

Z. Hu, The Univ. of Iowa (United States); M. D. Abramoff, M. Niemeijer, The Univ. of Iowa Hospitals and Clinics (United States); M. K. Garvin, The Univ. of Iowa (United States)

Segmenting vessels in spectral-domain optical coherence tomography (SD-OCT) volumes is particularly challenging in the region near and inside the neural canal opening (NCO).

Furthermore, accurately segmenting them in color fundus photographs also presents a challenge near the projected NCO. However, both modalities also provide complementary information to help indicate vessels, such as a better NCO contrast from the NCO-aimed OCT projection image and a better vessel contrast inside the NCO from fundus photographs. We thus present a novel multimodal automated classification approach for simultaneously segmenting vessels in SD-OCT volumes and fundus photographs, with a particular focus on better segmenting vessels near and inside the NCO by using a combination of their complementary features. In particular, in each SD-OCT volume, the algorithm pre-segments the NCO using a graph-theoretic approach and then applies oriented Gabor wavelets with oriented NCO-based templates to generate OCT image features. After fundus-to-OCT registration, the fundus image features are computed using Gaussian filter banks and combined with OCT image features. A k-NN classifier is trained on 5 and tested on 10 randomly chosen independent image pairs of SD-OCT volumes and fundus images from 15 subjects with glaucoma. Using ROC analysis, we demonstrate an improvement over two closest previous works performed in single modal SD-OCT volumes with an area under the curve (AUC) of 0.87 (0.81 for our and 0.72 for Niemeijer's single modal approach) in the region around the NCO and 0.90 outside the NCO (0.84 for our and 0.81 for Niemeijer's single modal approach).

7962-04, Session 2

Simultaneous detection of landmarks and key-frames in Cardiac perfusion MRI using a joint spatial-temporal model

X. Lu, H. Xue, M. Jolly, C. Guetter, Siemens Corporate Research (United States); P. Kellman, L. Hsu, A. E. Arai, National Institutes of Health (United States); S. Zuehlsdorff, Siemens Corporation (United States); A. Littmann, Siemens AG (Germany); B. Georgescu, J. Guehring, Siemens Corporate Research (United States)

Cardiac perfusion magnetic resonance imaging (MRI) has proven clinical significance in diagnosis of heart diseases. However, analysis of perfusion data is time-consuming. Automatic detection of anatomic landmarks and key-frames from perfusion MR sequences is important in facilitating fully automated perfusion analysis. Learning-based object detection methods have demonstrated their capabilities to handle large variations of the object by exploring local context. Conventional 2D approaches takes into account spatial context only. Temporal signals in perfusion data present a strong cue for anchoring. We propose a joint context model to encode both spatial and temporal evidence. In addition, our spatial context is constructed not only based on the landmark of interest, but also the landmarks that are correlated in the neighboring anatomies. A discriminative model is learned through a probabilistic boosting tree. A marginal space learning strategy is applied to efficiently learn and search in a high dimensional parameter space. A fully automatic system is developed to simultaneously detect anatomic landmarks and key frames in both RV and LV from perfusion sequences. The proposed approach was evaluated on a database of 373 cardiac perfusion MRI sequences from 77 patients. Experimental results of a 4-fold cross validation show superior landmark detection accuracy of the proposed joint spatial-temporal approach to the 2D approach that is based on spatial context only.

7962-05, Session 2

Statistical fusion of continuous labels: identification of cardiac landmarks

F. Xing, S. Soleimanifard, J. L. Prince, The Johns Hopkins Univ. (United States); B. A. Landman, Vanderbilt Univ. (United States)

Image labeling is an essential task for evaluating and analyzing

morphometric features in medical imaging data. Labels can be obtained by either human interaction or automated segmentation algorithms. However, both approaches for labeling suffer from inevitable error due to noise and artifact in the imaging data. The Simultaneous Truth And Performance Level Estimation (STAPLE) algorithm was developed to combine multiple rater decisions and simultaneously estimate unobserved true labels as well as each rater's level of performance (i.e., reliability). A generalization of STAPLE for the case of continuous-valued labels has also been proposed. In this paper, we first show that with the proposed Gaussian distribution assumption, this continuous STAPLE formulation yields equivalent likelihoods for the bias parameter, which means that the bias parameter-one of the key performance indices-is actually indeterminate. We resolve this ambiguity by augmenting the STAPLE expectation maximization formulation to include a priori probabilities on the performance level parameters, which enables simultaneous, meaningful estimation of both the rater bias and variance performance measures. We evaluate and demonstrate the efficacy of this approach both in simulations and through a human rater experiment involving the identification the intersection points of the right ventricle and the left ventricle in CINE cardiac data.

7962-06, Session 2

Automated planning of ablation targets in atrial fibrillation treatment

J. Keustermans, S. De Buck, H. Heidbüchel, P. Suetens, Katholieke Univ. Leuven (Belgium)

Catheter based radiofrequency ablation is used as an invasive treatment of atrial fibrillation. This procedure is often guided by the use of 3D anatomical models from CT, MRI or rotational angiography. Prespecified target ablation lines accurately guide the catheter towards the targets during the intervention. The planning stage, however, can be time consuming and operator dependent which is suboptimal both from a cost and health perspective. Therefore, we present a novel statistical model-based algorithm for locating target ablation lines on 3D rotational angiography images. Based on a training data set of 20 patients, consisting of 3D rotational angiography images with 30 manually indicated ablation points, a statistical local appearance and shape model is built. The local appearance model is based on local image descriptors to capture the intensity patterns around each ablation point. The local shape model is constructed by embedding the ablation points in an undirected graph and imposing that each ablation point only interacts with its neighbors. Identifying the ablation points on a new 3D rotational angiography image is performed by proposing a set of possible candidate locations for each ablation point, as such, converting the problem into a labeling problem. The algorithm is validated using a leave-one-out-approach on the training data set, by computing the distance between the ablation lines obtained by the algorithm and the manually identified ablation points. The distance error is equal to 3.8±2.9mm. As ablation lesion size is around 5-7mm, this is sufficient for the application.

7962-07, Session 2

Groupwise registration of cardiac perfusion MRI sequences using normalized mutual information in high dimension

S. Hamrouni, N. F. Rougon, TELECOM & Management SudParis (France); F. Prêteux, Mines ParisTech (France)

In perfusion MRI (p-MRI) exams, short-axis (SA) image sequences are captured at multiple slice levels along the long-axis of the heart during the transit of a vascular contrast agent (Gd-DTPA) through the cardiac chambers and muscle.

Compensating cardio-thoracic motions is a requirement for enabling computer-aided quantitative assessment of myocardial ischaemiafrom contrast-enhanced p-MRI sequences.

The classical paradigm consists of registering each sequence frame on a reference image using some intensity-based matching criterion.

In this paper, we introduce a novel unsupervised method for the spatio-temporal groupwise registration of cardiac p-MRI exams based on normalized mutual information (NMI) between high-dimensional feature distributions.

Here, local contrast enhancement curves are used as a dense set of spatio-temporal features, and statistically matched through variational optimization to a target feature distribution derived from a registered reference template. The hard issue of probability density estimation in high-dimensional state spaces is bypassed by using consistent geometric entropy estimators, allowing NMI to be computed directly from feature samples.

Specifically, a computationally efficient kth-nearest neighbor estimation framework is retained, leading to closed-form expressions for the gradient flow of NMI over finite- and infinite-dimensional motion spaces.

Experiments on simulated and natural datasets suggest the accuracy and relevance of the model for the rigid and non rigid registration of p-MRI exams.

7962-08, Session 2

A comparison of cost functions for data-driven motion estimation in myocardial perfusion SPECT imaging

J. M. Mukherjee, Univ. of Massachusetts Medical School (United States); B. F. Hutton, Univ. College Hospital (United Kingdom); M. A. King, Univ. of Massachusetts Medical School (United States)

In myocardial perfusion SPECT imaging patient motion during acquisition causes severe artifacts in about 5% of studies. Motion estimation strategies commonly used are a) data-driven, where the motion is determined by registration and checking consistency with the SPECT acquisition data, and b) external surrogate-based, where the motion is obtained from a dedicated motion-tracking system. In this paper a data-driven strategy similar to a 2D-3D registration scheme with multiple views is investigated, using a partially or fully reconstructed heart for the 3D model. Here, both the fully- and partially-reconstructed heart have inaccuracies, the former due to motion blur and the latter due to limited angle artifacts resulting from using only a part of the SPECT projections acquired while the patient maintained the same pose. The goal of this paper is to compare the performance of different cost-functions in quantifying consistency with the SPECT projection data for motion estimation as the image-quality of the 3D model degrades. Six intensity-based metrics- Mean-squared difference (MSD), Mutual information (MI), Normalized Mutual information NMI), Pattern intensity (PI), normalized cross-correlation (NCC) and Entropy of the difference (EDI) were studied so far. Quantitative and qualitative analysis of the performance is reported using Monte-Carlo simulations of a realistic heart phantom including degradation factors such as attenuation, scatter and collimator blurring. Pattern intensity and Mutual Information were observed to have the best performance in terms of average position error and stability with 3D model degradation.

7962-09, Session 2

Automatic evaluation of the Valsalva sinuses from cine-MRI

C. Blanchard, T. Sliwa, A. Lalande, P. Mohan, O. Bouchot, Y. Voisin, Univ. de Bourgogne (France)

MRI appears to be particularly attractive for the study of the Sinuses of Valsalva (SV), however there is no global consensus on their suitable measurements. In this paper, we propose a new method, based on mathematical morphology and combining numerical geodesic reconstruction with area estimation, to automatically evaluate the SV from cine-MRI in a cross-sectional orientation. It consists in the extraction of the shape, the detection of relevant points (commissures,

cusps and centre of the SV), the measure of relevant distances and in a classification of the valve as bicuspid or tricuspid by a metric evaluation of the SV. Our method was tested on 23 patient data sets and radii calculations were compared with manual processing. The classification of the valve as tricuspid or bicuspid was correct for all the cases. On the patient data sets, there are excellent correlation and concordance between manual and automatic measurements for images at diastole ($r= 0.97$; $y = x - 0.02$; $p<10-5$; mean of differences = -0.1 mm; standard deviation of differences = 2.3 mm) and at systole ($r= 0.96$; $y = 0.97 x + 0.80$; $p<10-5$; ; mean of differences = -0.1 mm; standard deviation of differences = 2.4 mm) phases. The cross-sectional orientation of the image acquisition plane conjugated with our automatic method provides reliable morphometric evaluation of the SV, based on the automatic location of the centre of the SV, of the commissure and the cusp positions. Measures of distances between relevant points allow a precise evaluation of each cusp of the SV.

7962-10, Session 3

A variational approach to bone segmentation in CT images

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We present a variational approach for segmenting bone structures in Computed Tomography~(CT) images. We introduce a novel functional on the space of image segmentations and subsequently minimize this functional through a gradient descent partial differential equation. The functional we propose provides a measure of similarity of the intensity characteristics of the bone and tissue regions through a comparison of their cumulative distribution functions. We perform the minimization of our proposed functional using level set partial differential equations. In addition to numerical stability, this yields topology independence, which is especially useful in the context of CT bone segmentation where a bone region may consist of several disjoint pieces. Finally, we present an extensive validation of our method against expert manual segmentation on CT images of the wrist, ankle, foot, and pelvis.

7962-11, Session 3

Fully automatic detection of the vertebrae in 2D CT images

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Knowledge about the vertebrae is a valuable source of information for several annotation tasks. In recent years, the research community spent a considerable effort for detecting, segmenting and analyzing the vertebrae and the spine in various image modalities like CT or MR. Most of these methods rely on prior knowledge like the location of the vertebrae or other initial information like the manual detection of the spine. Furthermore, the majority of these methods require a complete volume scan. With the existence of use cases where only a single slice is available, there arises a demand for methods allowing the detection of the vertebrae in 2D images. In this paper, we propose a fully automatic and parameterless algorithm for detecting the vertebrae in 2D CT images. Our algorithm starts with detecting candidate locations by taking the density of bone-like structures into account. Afterwards, the candidate locations are extended into candidate regions for which certain image features are extracted.

The resulting feature vectors are compared to a database of previously annotated and processed images in order to determine the best candidate region. In a final step, the result region is readjusted until convergence to a locally optimal position. Our new method is validated on a real world data set of more than 7400 images of 19 patients being annotated by a clinician in order to provide a realistic ground truth.

7962-12, Session 3

Segmentation of vertebral bodies in MR and CT images based on a 3D deterministic model

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Evaluation of vertebral deformations is of great importance in clinical diagnostics and therapy of pathological conditions affecting spine. Although modern clinical practice is oriented towards the computed tomography (CT) and magnetic resonance (MR) imaging techniques, which provide a detailed three-dimensional (3D) representation of vertebrae, the established methods for the evaluation of vertebral deformations provide only two-dimensional (2D) geometrical descriptions. Segmentation of vertebrae in 3D may therefore not only improve their visualization, but also provide conditions for reliable and accurate 3D measurements of vertebral deformations. In this paper we propose a method for 3D segmentation of individual vertebral bodies in CT and MR images. Initialized with a single point inside the vertebral body, the segmentation is performed by optimizing the parameters of a 3D deterministic model of vertebral body to achieve the best match of the model to the vertebral body in the image. The performance of the proposed method was evaluated on five CT (40 vertebrae) and five T2-weighted MR (40 vertebrae) that contain normal and pathological vertebrae. The results show that the proposed method can be used for 3D segmentation of vertebral bodies in CT and MR images and that the proposed model can describe a variety of vertebral body shapes. The method may be therefore used for initializing whole vertebra segmentation or for evaluation of vertebral body deformations.

7962-13, Session 3

Manifold learning for automatically predicting articular cartilage morphology in the knee with data from the osteoarthritis initiative (OAI)

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Osteoarthritis (OA) is a degenerative, debilitating disease with a large socio-economic impact which results in a major impact on the quality of life for individuals. Many previous studies do not look at large cohorts for quantitative imaging analysis for OA. This study looks to manifold learning as an automatic approach to harness the plethora of data provided by the Osteoarthritis Initiative (OAI). We construct a Laplacian Eigenmap embedding of articular cartilage appearance from MR images of the knee, using multiple MR sequences. A region of interest (ROI) defined as the weight bearing medial femur is automatically located in all images through non-rigid registration techniques. A pairwise intensity based similarity measure is computed between all images, resulting in a fully connected graph, where each vertex represents an image and the weight of edges is the similarity measure. Spectral analysis is then applied to these pairwise similarities, which acts to reduce the dimensionality non-linearly and embeds these images in a manifold representation. In the manifold space, images that are close to each other are considered to be more "similar" than those far away. In the experiment presented here we use manifold learning to automatically predict the morphological changes in the articular cartilage by using the co-ordinates of the images in the manifold space as independent variables for multiple linear regression. We find statistically significant correlations between our predictors and the results presented in the literature.

7962-14, Session 3

Determination of vertebral pose in 3D by minimization of vertebral asymmetry

T. Vrtovec, F. Pernuš, B. Likar, Univ. of Ljubljana (Slovenia)

The pose of a vertebra in three dimensions (3D) may provide valuable information for quantitative orthopedic measurements or initalization of techniques for segmentation of spinal and vertebral structures. We propose a method for automated determination of the vertebral pose in 3D, which determines the position and rotation of the 3D vertebral coordinate system in the 3D image coordinate system. By searching for the hypothetical points, which are located where the boundaries of anatomical structures would have maximal symmetrical correspondences when mirrored over the planes that define the 3D vertebral coordinate system, the asymmetry of vertebral anatomical structures is minimized in an iterative registration scheme. The method was evaluated on 14 normal and 14 scoliotic vertebrae in images acquired by computed tomography (CT). For each vertebra, 1000 randomly initialized experiments were performed and the results show that the vertebral pose can be successfully determined in 3D with mean accuracy of 0.5 mm and 0.6 degrees and mean precision of 0.17 mm and 0.17 degrees in terms of 3D position and 3D rotation, respectively.

7962-15, Session 3

Femur specific polyaffine model to regularize the log-domain demons registration

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Osteoarticular allograft transplantation is a popular treatment method in wide surgical resections with large defects. For this reason hospitals are building bone data banks. Performing the optimal allograft selection on bone banks is crucial to the surgical outcome and patient recovery. However, current approaches are very time consuming hindering an efficient selection. We present an automatic method based on registration of femur bones to overcome this limitation. We introduce a new regularization term for the log-domain demons algorithm. This term replaces the standard Gaussian smoothing with a femur specific polyaffine model. The polyaffine femur model is constructed with two affine (femoral head and condyles) and one rigid (shaft) transformation. Our main contribution in this paper is to show that the demons algorithm can be improved in specific cases with an appropriate model. We are not trying to find the most optimal polyaffine model of the femur, but the simplest model with a minimal number of parameters. There is no need to optimize for different number of regions, boundaries and choice of weights, since this fine tuning will be done automatically by a final demons relaxation step with Gaussian smoothing. The newly developed synthesis approach provides a clear anatomically motivated modeling contribution through the specific three component transformation model, and clearly shows a performance improvement (in terms of anatomical meaningful correspondences) on 146 CT images of femurs compared to a standard multiresolution demons. In addition, this simple model improves the robustness of the demons while preserving its accuracy. The ground truth are manual measurements performed by medical experts.

7962-16, Session 3

Segmentation of knee joints in x-ray images using decomposition-based sweeping and graph search

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Plain radiography is an effective and efficient tool to diagnose knee illnesses and injuries. However, segmenting and analyzing knee radiographs with good quality is a challenging problem. In this paper, we study the problem of segmenting the bones of knee joints in X-ray images. We first apply the Gaussian high-pass filter to remove homogeneous regions, which are unlikely to appear on the bone contours. We then presegment the bones and develop a novel decomposition-based sweeping algorithm for extracting bone contour topology from the filtered skeletonized images. Our sweeping algorithm decomposes the bone structures into several relatively simple components and deals with each component separately based on its geometric characteristics using a sweeping strategy. Based on the presegmentation, we construct a graph to model the bone topology and apply an optimal graph search algorithm to optimize the segmentation results (with respect to our cost function on the bone boundaries). Our segmented results match well with the manual traced ones produced by radiologists. Our segmentation approach is a valuable tool for assisting radiologists and X-ray technologists in clinical practice and training.

7962-61, Poster Session

Log-Euclidean free-form deformation

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The Free-Form Deformation (FFD) algorithm is a widely used method for non-rigid registration. Modifications have previously been proposed to ensure topology preservation and invertibility within this framework. However, in practice, none of these yield the inverse transformation itself, and one loses the parsimonious B-spline parametrisation. We present a novel log-Euclidean FFD approach in which a spline model of a stationary velocity field is exponentiated to yield a diffeomorphism, using an efficient scaling-and-squaring algorithm. The log-Euclidean framework allows easy computation of a consistent inverse transformation, and offers advantages in group-wise atlas building and statistical analysis. We optimise the Normalised Mutual Information plus a regularisation term based on the Jacobian determinant of the transformation, and we present a novel analytical gradient of the latter. The proposed method has been assessed against a fast FFD implementation using simulated T1- and T2-weighted magnetic resonance brain images. The overlap measures between propagated grey matter tissue probability maps used in the simulations show similar results for both approaches; however, our new method obtains more reasonable Jacobian values, and yields inverse transformations.

7962-62, Poster Session

Correspondence estimation from non-rigid motion information

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The DIET (Digital Image Elasto Tomography) system is a novel approach to screen for breast cancer using only optical imaging information of the surface of a vibrating breast. 3D tracking of skin surface motion without the requirement of external markers is desirable. A novel approach to establish point correspondences using pure skin images is presented here. Instead of the intensity, motion is used as the primary feature, which can be extracted using optical flow algorithms. Taking sequences of multiple frames into account, this motion information alone is accurate and unambiguous enough to allow for a 3D reconstruction of the breast surface motion. Two approaches for this correspondence, direct and probabilistic, are presented here, suitable for dierent levels of calibration information accuracy. Reconstructions show that the results obtained using these methods are comparable in accuracy to marker-based

methods while signicantly increasing resolution. The presented method has signicant potential in optical tissue deformation and motion sensing.

7962-63, Poster Session

Co-registration of high resolution MRI sub-volumes in non-human primates

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Dynamic structural and functional remodeling of the Central Nervous System occurs throughout the lifespan of the organism from the molecular to the systems level. MRI offers several advantages to observe this phenomenon: it is non-invasive and non-destructive, the contrast can be tuned to interrogate different tissue properties and imaging resolution can range from cortical columns to whole brain networks in the same session. To measure these changes reliably, functional maps generated over time with high resolution fMRI need to be registered accurately. This article presents a new method for registering automatically thin cortical MR volumes that are aligned with the functional maps. These acquisitions focus on the primary somato-sensory cortex, a region in the anterior parietal part of the brain, responsible for fine touch and proprioception. Currently, these slabs are acquired in approximately the same orientation from acquisition to acquisition and then registered by hand. Because they only cover a small portion of the cortex, their direct automatic registration is difficult. To address this issue, we propose a method relying on an intermediate image, acquired with a surface coil that covers a larger portion of the head to which the slabs can be registered. Because images acquired with surface coils suffer from severe intensity attenuation artifact, we also propose a method to register these. The results from data sets obtained with three squirrel monkeys show a registration accuracy of thirty micrometers.

7962-64, Poster Session

Motion analysis for duplicate frame removal in wireless capsule endoscope

H. G. Lee, M. K. Choi, S. Lee, Inha Univ. (Korea, Republic of)

Wireless capsule endoscopy (WCE) has been intensively researched due to its convenience in diagnosis and extended detection coverage for some diseases, such as bleeding in small intestine. In spite of these benefits, a WCE based diagnosis confronts a significant barrier for quick diagnosis such that a trained diagnostician must examine a huge amount of recorded sequence for close investigation, normally over 2 hours. Typically, a full diagnosis covering the entire human digestive system requires 8 to 12 hours of examination, which consists of 120,000 image frames on average.

In this work, we propose a machine vision based method to reduce the diagnosis time by detecting duplicated recordings at the same spatial locations in small intestine, which is caused by the imaging nature of WCE, i.e., peristalsis based movements. Our method consists of the following steps. First, we extract a set of optical flow vectors from the sequences. Second, we perform an ego-motion analysis of the WCE by dividing the vectors for a frame into nine regions, such as boundary regions for classification and one center region for global motion adjustment. Finally, we detect the backward-moving motions from the flow patterns consistently heading to a vanishing point, i.e., the center of image. We evaluated our detection accuracy by comparing the results with the ground truth measures, which is found by a domain expert. The experimental results showed that our method achieved 92.85% correct detection ratio for a WCE video obtained from a real human subject.

7962-65, Poster Session

Fully automated prone-supine coregistration in computed tomographic colonography

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A fully automated, anatomically-based procedure is developed for the coregistration of prone and supine scans in computed tomographic colonography (CTC). Haustral folds, teniae coli, and other anatomic landmarks in the colon are extracted from the segmented colonic lumen. These anatomic landmarks serve as the basis for iterative optimization-based matching of the colonic surface between the prone and supine scan sets. The three-dimensional coregistration is computed efficiently with a two-dimensional filet representation of the colon by estimating the stretching deformation and the circumferential rotation deformation between scans. The circumferential positions of longitudinal structures such as teniae coli are used to estimate rotational deformation; haustral folds are used to estimate longitudinal (stretching) deformation, while other landmarks and anatomical considerations are used to constrain the range of allowable deformations. The proposed method is robust to changes in the detected anatomical landmarks such as the obscuration or apparent bifurcation of teniae coli. Preliminary validation of the method (using independent features such as polyps and diverticula) in the publicly available Walter Reed CTC data set shows excellent coregistration accuracy - 57 manually identified features are automatically coregistered with a mean three-dimensional error of 16.4mm. The coregistration allows points of interest in one scan to be automatically located in the other, leading to an expected improvement in per-patient read time and a significant reduction in the cost of CTC.

7962-66, Poster Session

Local rigid registration for multimodal texture feature extraction from medical images

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The joint extraction of texture features from medical images of different modalities requires an accurate image registration at the target structures. In many cases rigid registration of the entire images does not achieve the desired accuracy whereas deformable registration is too complex and may result in undesired deformations. This paper presents a novel region of interest alignment approach based on local rigid registration enabling image fusion for multimodal texture feature extraction. First rigid registration on the entire images is performed to obtain an initial guess. Then small cubic regions around the target structure are clipped from all images and individually rigidly registered.

The approach was applied to extract texture features in clinically acquired CT and MR images from lymph nodes in the oropharynx for an oral cancer reoccurrence prediction framework. Visual inspection showed that in all of the 30 cases at least a subtle misalignment was perceivable for the globally rigidly aligned images. After applying the presented approach the alignment of the target structure significantly improved in 19 cases. In 12 cases no alignment mismatch whatsoever was perceptible without requiring the complexity of deformable registration and without deforming the target structure.

Further investigation showed that if the resolutions of the individual modalities differ significantly, partial volume effects occur, diminishing the significance of the multimodal features even for perfectly aligned images.

7962-67, Poster Session

Registration of multi-view apical 3D echocardiography images

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Real-time three-dimensional echocardiography (RT3DE) is a non-invasive method to visualize the heart. Disadvantageously, it suffers from non-uniform image quality and a limited field of view. Image quality can be improved by the fusion of multiple echocardiography images. Successful registration of the images is essential for prosperous fusion. Therefore, this study examines the performance of different methods for intrasubject registration of multi-view apical RT3DE images.

A total of 14 data sets was annotated by two observers who indicated the position of the apex and four points on the mitral valve ring. These annotations were used to evaluate the registration. Multi-view end-diastolic (ED) as well as end-systolic (ES) images were rigidly registered in a multi-resolution strategy. The performance of single-frame and multi-frame registration was examined. Multi-frame registration optimizes the metric for several time frames simultaneously. Furthermore, the suitability of mutual information (MI) as similarity measure was compared to normalized cross-correlation (NCC). For initialization of the registration, a transformation that describes the probe movement was obtained by manually registering five representative data sets.

It was found that multi-frame registration can improve registration results with respect to single-frame registration. Additionally, NCC outperformed MI as similarity measure. If NCC was optimized in a multi-frame registration strategy including ED and ES time frames, the performance of the automatic method was comparable to that of manual registration.

In conclusion, automatic registration of RT3DE images performs as good as manual registration. As registration precedes image fusion, this method can contribute to improved quality of echocardiography images.

7962-68, Poster Session

Robust linear registration of CT images using random regression forests

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Global linear registration (rigid-similarity-affine) is a necessary first step for many different tasks in medical image analysis. Comparing longitudinal studies [1], cross-modality fusion [2], and many other applications depend heavily on the success of the automatic registration. The robustness and efficiency of this step is crucial as it affects all proceeding operations.

Most common techniques cast the linear registration problem as the minimization of a global energy function based on the image intensities. Although these algorithms have proved useful, their robustness in fully automated scenarios is still an open question. In fact the optimization step often gets caught in local minima yielding unsatisfactory results. Recent algorithms constrain the space of registration parameters by exploiting implicit or explicit organ segmentations, thus increasing robustness [4, 5].

In this work we propose a novel robust algorithm for automatic global linear image registration. Our method uses random regression forests to estimate posterior distributions for the locations of anatomical structures - represented as axis aligned bounding boxes [6]. These posterior distributions are later integrated in a global linear registration algorithm. The biggest advantage of our algorithm is that it does not require pre-defined segmentations or regions yet it yields robust registration results. We compare the robustness of our algorithm with that of the state of the art Elastix toolbox [7]. Validation is performed via 1464 pair-wise registrations in a database of very diverse 3D CT images. We show that our method decreases the “failure” rate of the global linear registration from 12.5% (Elastix) to only 1.9%.

7962-69, Poster Session

Ridge-based retinal image registration algorithm involving OCT fundus images

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This paper proposes an algorithm for retinal image registration involving OCT fundus images (OFIs). The first application of the algorithm is to register OFIs with color fundus photographs (CFPs); such registration between multimodal retinal images can help correlate features across imaging modalities, which is important for both clinical and research purposes. The second application is to perform the montage of several OFIs, which allow us to construct 3D OCT images over a large field of view out of separate OCT datasets. In the registration of individual image pairs, blood vessel ridges are used as features for registration. A brute force search is used to achieve an initial coarse registration based on the similarity function, and then an Iterative Closest Point (ICP) algorithm for a more accurate registration. To achieve the montage of several OFIs, following the registration between individual OFI pairs with sufficient overlaps, the global montage parameters are calculated by minimizing the sum of the square distances between all these matched pixel pairs. In the first experiment for registration between OFIs and CFPs from 19 subjects, three different transformation models (similarity, affine, and quadratic) were considered, and the affine transformation was the best choice, giving satisfying performance. In the second experiment for the montage of OFIs, 12 sets of several partially overlapping OFIs were tested. We found that the two techniques, preprocessing of OFIs to enhance blood vessel visibility, and inclusion of CFPs in the montage, can improve montage performance for the abnormal subjects.

7962-70, Poster Session

2D to 3D ultrasound registration for robotically assisted laparoscopic radical prostatectomy

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Prostate cancer is the most prevalent cancer amongst western males, accounting for 27% of all new cancer cases in Canadian men in 2010. Robotically assisted laparoscpic radical prostastectomy (RALP) is an effective approach to resect the diseased organ, with stereoscopic views of the targeted tissue improving the dexterity of the surgeons. However, since the laparoscopic view acquires only the surface image of the tissue, the underlying distribution of the cancer within the organ is not observed, making it difficult to make informed decisions on surgical margins and sparing of neurovascular bundles. One option to address this problem is to exploit registration to integrate the laparoscopic view with images of preoperatively acquired dynamic contrast enhanced (DCE) MRI that can demonstrate the regions of malignant tissue within the prostate. Such a view potentially allows the surgeon to visualize the location of the malignancy with respect to the surrounding neurovascular structures, permitting a tissue-sparing strategy to be formulated directly based on the observed tumour distribution which provides preserving erectile function and urinary continence. However, in order to realize such image integration, the pre-operative image needs to be fused with the prostate, and at least during the initial stages of the operation, the prostate must

to be tracked in real time so that the pre-operative MR image remains registered. In this study, we propose and investigate a novel 2D to 3D ultrasound image registration algorithm to track the prostate motion with an accuracy of 4.01(+/-)1.18mm.

7962-71, Poster Session

Multimodal image registration by edge attraction and regularization using a B-spline grid

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Multi modal image registration enables images from different modalities to be analyzed in the same coordinate system. The class of B-spline-based methods that maximize the Mutual Information between images produce satisfactory result in general, but are often complex and can converge slowly. The popular Demons algorithm, while being fast and easy to implement, produces unrealistic deformation fields and is sensitive to illumination differences between the two images, which makes it unsuitable for multi-modal registration in its original form.

We propose a registration algorithm that combines a B-spline grid with deformations driven by image forces as in Demons registration. The algorithm is easy to implement and is robust against large differences in the appearance between the images to register. The deformation is driven by attraction-forces between the edges in both images, and a B-spline grid is used to regularize the sparse deformation forces. The grid is updated using an original approach by weighting the deformation forces for each pixel individually with the (multiplied) edge strengths. This approach makes the algorithm perform well even if not all corresponding edges are present.

We report preliminary results by applying the proposed algorithm to a set (multi-modal) test images. In addition, the algorithm is used to register test images to manually drawn line images in order to evaluate the algorithm's robustness. While the results are promising, the method will have to be quantitatively evaluated on larger test data, and should be compared against other state of the art registration algorithms.

7962-72, Poster Session

Nonrigid registration of multiphoton microscopy images using B-splines

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Optical microscopy poses many challenges for digital image analysis. One particular challenge includes correction of image artifacts due to respiratory motion from specimens imaged in vivo. We describe a non-rigid registration method using B-splines to correct these motion artifacts. Current attempts at non-rigid medical image registration have typically involved only a single pair of images. Extending these techniques to an entire series of images, possibly comprising hundreds of images, is presented in this paper. Our method involves creating a uniform grid of control points across each image in a stack. Each control point is manipulated by optimizing a cost function consisting of two parts: a term to determine image similarity, and a term to evaluate deformation grid smoothness. This process is repeated for all images in the stack. Analysis is evaluated using block motion estimation and other visualization techniques.

7962-73, Poster Session

Efficient registration method of medical images using GPU

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Registration of medical images is an important problem. However, automatic image-based registration is computationally expensive. In this paper, we propose an efficient rigid registration method based on mutual information using graphics processing unit (GPU). Mutual-information-based registration methods require the joint histogram computation. Although GPU can provide high performance computing, the joint histogram has a large number of bins, and the computation of such histogram is not suitable for GPU whose shared memory is limited. The proposed method computes the joint histogram by computing multiple one-dimensional histograms and combining them taking advantage of the fact that one image (the reference image) is not transformed during the registration process. Therefore, the proposed method can be efficiently applied on GPU even with limited shared memory. Experimental results show that the proposed method is about 140 times faster than a standard implementation on a CPU, and 2.6 times faster than previous methods using GPU.

7962-74, Poster Session

Evaluation of optimization methods for intensity-based 2D-3D registration in x-ray guided interventions

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Although the performances of various similarity measures for the application of 2D-3D registration have been well evaluated, the influence of the optimization method on the performance has not been investigated. We have evaluated the accuracy and capture range of intensity-based 2D-3D registration using seven different optimization methods, in combination with three similarity measures that had the best performances in previous studies. The results show that the capture range of a similarity measure can increase significantly when a suitable optimization method is used. The best results were obtained with gradient correlation in combination with nonlinear conjugate gradient.

7962-75, Poster Session

Evaluation of multi atlas-based approaches for the segmentation of the thyroid gland in IMRT head-and-neck CT images

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Segmenting the thyroid gland in head-and-neck CT images for IMRT treatment planning is of great importance. In this work, we evaluate and compare multi-atlas methods to segment this structure. The various methods we evaluate range from using a single average volume representative of the population to selecting one or several reference volumes based on several similarity measures. We also compare ways to combine segmentation results obtained with several atlases, i.e., majority rule and STAPLE, which is a commonly used method to combine results produced by several segmentation algorithms.

7962-76, Poster Session

Automatic skull-stripping of rat MRI/DTI scans and atlas building

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3D Magnetic Resonance (MR) and Diffusion Tensor Imaging (DTI) have become important noninvasive tools for the study of animal models of brain development and neuropathologies. Fully automated analysis methods adapted to rodent scale for these images will allow high-throughput studies. A fundamental first step for most quantitative analysis algorithms is skull-stripping, which refers to the segmentation of the image into two tissue categories, brain and non-brain. In this manuscript, we present a fully automatic skull-stripping algorithm in an atlas-based manner. We also demonstrate how to either modify an external atlas or to build an atlas from the population itself to present a self-contained approach. We applied our method to three datasets of rat brain scans, at different ages (PND5, PND14 and adult), different study groups (control, ethanol exposed, intrauterine cocaine exposed), as well as different image acquisition parameters. We validated our method by comparing the automated skull-strip results to manual delineations performed by our expert, which showed a discrepancy of less than a single voxel on average. We thus demonstrate that our algorithm can robustly and accurately perform the skull-stripping within one voxel of the manual delineation, and in a fraction of the time it takes a human expert.

7962-77, Poster Session

Evaluating and improving atlas-based segmentation using spatial distance maps

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Atlas-based segmentation is an increasingly popular method of automatically computing a segmentation. In the past, results of atlas-based segmentation have been evaluated using a binary overlap measure such as the Dice or Jaccard coefficients. However, in the first part of this paper we will argue and show that binary overlap measures are insensitive to local deviations. As a result, a segmentation that is judged to be of good quality when using such a measure may have large local deviations that may be problematic in clinical practice. In this paper, the spatial distance map is proposed as an alternative measure to evaluate the results of atlas-based segmentation, as it gives more local information and therefore allows the detection of large local deviations.

In most current atlas-based segmentation methods, the results of multiple atlases are combined to a single segmentation in a process called 'label fusion'. In a label fusion process it is important that segmentations with a high quality can be distinguished from those with a low quality.

In the second part of the paper we will use the spatial distance map as a similarity measure during label fusion. We will present a modified version of the previously proposed SIMPLE algorithm, which selects propagated atlas segmentations based on their similarity with a preliminary estimate of the ground truth segmentation. The SIMPLE algorithm previously used the Dice coefficient as a similarity measure and in this paper we demonstrate that, using the spatial distance map instead, the results of atlas-based segmentation significantly improve.

7962-78, Poster Session

Group-wise automatic mesh-based analysis of cortical thickness

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The analysis of neuroimaging data from pediatric populations presents several challenges. There are normal variations in brain shape from infancy to adulthood and normal developmental changes related to tissue maturation. Measurement of cortical thickness is one important way to analyze such developmental tissue changes.

We developed a novel framework that allows group-wise automatic mesh-based analysis of cortical thickness. Our analysis framework consists of a pipeline of C++ based automated 3D Slicer compatible modules. The approach is divided into four parts. First an individual pre-processing pipeline is applied on each subject to create genus-zero inflated white matter cortical surfaces with cortical thickness measurements. The second part performs an entropy-based group-wise shape correspondence on these meshes using a particle system, which establishes a trade-off between an even sampling of the cortical surfaces and the similarity of corresponding points across the population using sulcal depth information and spatial proximity. A novel automatic initial particle sampling is performed using a matched 98-lobe parcellation map prior to a particle-splitting phase. Third, corresponding re-sampled surfaces are computed with interpolated cortical thickness measurements, which are finally analyzed via a statistical vertex-wise analysis module.

This framework has been tested on a small pediatric dataset and incorporated in an open source C++ based high-level module called GAMBIT. GAMBIT's setup allows efficient batch processing, grid computing and quality control. The current research focuses on the use of an average template for correspondence and surface re-sampling, as well as thorough validation of the framework and its application to clinical pediatric studies.

7962-79, Poster Session

A totally deflated lung's CT image construction by means of extrapolated deformable registration

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A novel technique is proposed to construct CT image of a totally deflated lung using breath-hold lung's pre-operative CT images acquired during respiration. Such a constructed CT image would be very useful in performing tumor ablative procedures such as lung brachytherapy, which can aid in targeting the tumor for lung cancer treatment. To minimize motion within the target lung, tumor ablative procedures are frequently performed while the lung is totally deflated. Deflating the lung during such procedures renders pre-operative images ineffective for targeting the tumor, because those images correspond to the lung while it is partially inflated. Furthermore, the problem cannot be solved using intra-operative Ultrasound (US) images. This is because the quality of lung US images degrades substantially as a result of the residual air inside the deflated lung, thus it is not an effective intra-operative imaging modality by itself. One possible approach for image-guided lung brachytherapy is to register high quality preoperative CT images of the deflated lung with their corresponding low quality intra-operative US images. To obtain the CT images of deflated lung, a novel image construction technique is presented. The proposed technique was implemented using two deformable registration methods: multi-resolution B-spline and multi-resolution demons. The technique was applied to ex-vivo porcine lungs where results obtained were found to be very encouraging.

7962-80, Poster Session

An automated pipeline for cortical surface generation and registration of the cerebral cortex

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The human cerebral cortex is one of the most complicated structures in the body. It has a highly convoluted structure with much of the cortical sheet buried in sulci. Based on cytoarchitectural and functional imaging studies, it is possible to segment the cerebral cortex into several subregions. While it is only possible to differentiate the true anatomical subregions based on cytoarchitecture, the surface morphometry aligns closely with the underlying cytoarchitecture and provides features that allow the surface of the cortex to be parcellated based on the sulcal and gyral patterns that are readily visible on the MR images.

We have developed a fully automated pipeline for the generation and registration of cortical surfaces in the spherical domain. The pipeline initiates with the BRAINS AutoWorkup pipeline. Subsequently, topology correction and surface generation is performed to generate a genus zero surface and mapped to a sphere. Several surface features are then calculated to drive the registration between the atlas surface and other datasets. A spherical dieomorphic demons algorithm is used to co-register an atlas surface onto a subject surface.

A lobar based atlas of the cerebral cortex was created from a manual parcellation of the cortex. The atlas surface was then co-registered to ve additional subjects using a spherical dieomorphic demons algorithm. The labels from the atlas surface were warped on the subject surface and compared to the manual raters. The average Dice overlap index was 0.89 across all regions.

7962-81, Poster Session

Groupwise consistent image registration: a crucial step for the construction of a standardized near infrared hyperspectral teeth database

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Construction of a standardized near infrared (NIR) hyper-spectral teeth database is a first step in the development of a reliable diagnostic tool for quantification and early detection of dental diseases. Standardized diffuse reflectance hyper-spectral database was constructed by imaging 12 extracted human teeth with natural lesions of various degrees in the spectral range from 900 to 1700 nm with spectral resolution of 10 nm. Additionally, all the teeth were imaged by X-ray and digital color camera. The color and X-ray images of teeth were presented to the expert for localization and classification of the dental diseases, thereby obtaining a dental disease gold standard. Accurate transfer of the dental disease gold standard to the NIR spectral images is therefore of the utmost importance and was achieved by running the image registration in a groupwise manner, taking advantage of the multichannel image information and promoting image edges as the joint features for the spatial correspondence evaluation. By the proposed fully automatic multimodal groupwise registration method, images of new teeth samples can be accurately and reliably registered and then added to the standardized NIR hyper-spectral teeth database. Adding more samples increases the biological and pathophysiological variability of the NIR hyper-spectral teeth database and can importantly contribute to the objective assessment of the sensitivity and specificity of multivariate image analysis techniques used for the detection of dental diseases. Such assessment is essential for the development and validation of reliable qualitative and especially quantitative diagnostic tools based on NIR spectroscopy.

7962-82, Poster Session

Model-based segmentation of the facial nerve and chorda tympani in pediatric CT

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In image-guided cochlear implant surgery, where an electrode is implanted in the cochlea to treat hearing loss, access to the cochlea is achieved by drilling from the outer skull to the cochlea through the facial recess, a region bounded by the facial nerve and chorda. To exploit existing methods for computing automatically safe drilling trajectory, the facial nerve and chorda tympani need to be segmented. The effectiveness of traditional segmentation approaches to achieve this is severely limited because the facial nerve and chorda are small structures (~1 mm and ~0.3 mm in diameter, respectively) and exhibit poor image contrast. We have recently proposed a technique to achieve this task in adult patients, which relies on statistical models of the structures. These models contain intensity and shape information along the central axes of both structures. In this work we use the same method to segment pediatric scans. We show that substantial differences exist between the anatomy of children and the anatomy of adults, which lead to poor segmentation results when an adult model is used to segment a pediatric volume. We have built a new model for pediatric cases and we have applied it to ten scans. A leave-one-out validation experiment was conducted in which manually segmented structures were compared to automatically segmented structures. The maximum segmentation error is 1.3 mm. This result indicates that accurate segmentation of the facial nerve and chorda in pediatric scans is achievable, thus suggesting that safe drilling trajectories can also be computed automatically.

7962-83, Poster Session

Estimation of sufficient signal to noise ratio for texture analysis of magnetic resonance images

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We have studied the effect of background noise on texture analysis of muscle, bone marrow and fat tissues in 1.5 T magnetic resonance (MR) images using different statistical methods. Variable levels of noise were first added on 3-mm thick T2 image slices of voluntary subjects to simulate several signal-to-noise ratio (SNR) levels. For each original and simulated image, the values for 264 texture parameters were calculated by MaZda, a texture analysis toolkit. We also determined Fisher coefficients based on the texture parameter values in order to enable high discrimination between different tissues. Linear discriminant analysis (LDA) and two different nearest neighbour (NN) methods were then applied for the texture parameters with the highest Fisher values. Several training and test sets were used to approximate the variation in the classification results. All mentioned methods had closely the same classification accuracy, which in turn depended on the image SNR. We conclude that these tissues can be detected by texture analysis methods with a sufficient accuracy (90 %) especially if SNR is at least 30-40 dB, even though the separation of different muscles remains a very challenging task.

7962-84, Poster Session

Variational level-set segmentation and tracking of left ventricle using field prior

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This study investigates a novel method for tracking Left Ventricle (LV) curve in Magnetic Resonance (MR) sequences. The method focuses on energy minimization by level-set curve evolution. The level-set framework allows introducing knowledge of the field prior on the solution. The segmentation in each particular time relies not only on the current image but also segmented images from previous phase. We model a dynamic system for each frame, learned from the previous one. The method focuses on automatically segmenting the LV by constraining the solution by the learned field prior. Field prior is defined based on the experimental fact that the mean log intensity inside endo and epicardium is approximately stationary across a cardiac cycle. The solution is obtained by evolving a curve following the Euler-Lagrange minimization of a functional containing a field constraint. The latter measures the conformity of the field priori learned from first frame and the one estimated in each frame. Our preliminary results show that the obtained segmentation results are very well consistent with

those manually obtained by experts. Furthermore, we observed that the proposed field prior speeds up curve evolution significantly and reduces computation load.

7962-85, Poster Session

Novel segmentation method to identify left ventricular infarction in short-axis composite strain-encoded magnetic resonance images

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Composite Strain Encoding (C-SENC) is a new MRI technique for simultaneously acquiring cardiac functional and viability images. It combines the use of delayed-enhancement (DE) imaging to identify the infracted (dead) tissue inside the heart muscle and the ability to image myocardial deformation from the strain-encoding (SENC) imaging technique. In this work, a new unsupervised multi-stage method is proposed to objectively identify infarct heart tissues in the functional and viability images provided by C-SENC MRI. The method is based on sequential application of Bayes Classifier, Otsu Thresholding, Morphological Opening and the fuzzy C-means (FCM) clustering algorithm. The proposed method is tested on simulated heart images with various levels of superimposed noise and on images from eleven patients with and without myocardial infarction (MI). The resulting clustered images are compared with those marked up by expert cardiologists who assisted in validating results coming from the proposed method. Infarcted myocardium is correctly identified using the proposed method with high levels of accuracy and precision. The accuracy is found to be 92.14 - 98.46 % and the precision is found to be 84.22 - 89.94 %. The proposed technique allows for objectively identifying infarcted regions of the heart tissues, which would be potentially important for clinical decision-making in patients with MI.

7962-86, Poster Session

Automated analysis of infarct heterogeneity on delayed enhancement magnetic resonance images

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In this work we propose an automated infarct heterogeneity analysis algorithm for cardiac delayed enhancement magnetic resonance images (DE-MRI). Advantages of this algorithm are that it eliminates manual contouring of the left ventricle and automatically distinguishes infarct, "gray zone" (heterogeneous mixture of healthy and infarct tissue), and healthy tissue regions despite variability in intensity and noise across images. Specific challenges of automated analysis of infarct heterogeneity include that 1) the left ventricle may appear to be merged with the right ventricle by the existence of a septal infarct; 2) the detection of the epicardial, endocardial, infarct core and gray zone contours despite low contrast. The proposed algorithm is based on the roundness metric to locate the left ventricle, and detects endocardial, epicardial core and gray zone contours with a fast and automatic technique. Quantitative evaluation was performed on 12 patients. The automatically determined infarct core size and gray zone size showed high correlation with that derived from manual delineation (R2 = 0.91 for infarct core size and R2 = 0.87 for gray zone size). The automatic method shortens the evaluation to 5.6 ± 2.2 s per image, compared with 3 min for the manual method. These results indicate a promising method for automatic analysis of infarct heterogeneity with DE-MRI that should be beneficial for reducing variability in quantitative analysis and improving workflow.

7962-87, Poster Session

White matter lesion segmentation using machine learning and weakly labeled MR images

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We propose a fast, learning-based algorithm for segmenting white matter (WM) lesions from T1-weighted, T2-weighted, and FLAIR magnetic resonance (MR) brain images. Unlike most of the previously reported learning-based algorithms, which treat expert labeled lesion map as ground truth in training, the proposed algorithm only requires the user to provide a few regions of interest (ROI's) containing lesions. A k-means clustering algorithm is applied to segment these ROI's into areas. Based on the assumption that lesion voxels have higher intersity on FLAIR image, areas corresponding to lesions are identified and their joint probability distributions in T1, T2, and FLAIR images are learned. The segmentation is done by using the probability distributions to generate a confidence map of lesion and applying a graph-cut algorithm to label lesion voxels. This initial lesion label is used to further refine the probability distribution for the final lesion segmentation. The advantages of the proposed algorithm are: 1. By using the weak labels, we reduced the dependency of the segmentation performance on the expert discrimination of lesion voxels in the training samples; 2. The training can be done using labels generated by users with only general knowledge of brain anatomy and image characteristics of WM lesion, instead of these carefully labeled by experienced radiologists; 3. The algorithm is very fast. Interactive segmentation is possible. We test the algorithm on nine ACCORD-MIND MRI datasets. Experimental results show that the proposed algorithm agrees well with expert labels and outperforms a SVM-based WM lesion segmentation algorithm.

7962-88, Poster Session

Fast 4D segmentation of large datasets using graph cuts

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In this paper, we propose to use 4D graph cuts for the segmentation of large spatio-temporal (4D) datasets. Indeed, as 4D datasets grow in popularity in many clinical areas, so will the demand for efficient general segmentation algorithms. The graph cuts method has become a leading method for complex 2D and 3D image segmentation in many applications. Despite a few attempts in 4D, the use of graph cuts on typical medical volume quickly exceeds today's computer capacities. Among all existing graph cuts based methods the multilevel banded graph cuts is the fastest and uses the least amount of memory. Nevertheless, this method has its limitation. Memory becomes an issue when using large 4D volume sequences, and small structures become hardly recoverable when using narrow bands. We thus improve the boundary refinement efficiency by using a 4D competitive region growing. First, we construct a coarse graph at a low resolution with strong temporal links to prevent the shrink bias inherent of the graph cuts method. Second, we use a competitive region growing using a priority queue to capture all fine details. Leaks are prevented by constraining the competitive region growing within a banded region and by adding a viscosity term. This strategy yields results comparable to the multilevel banded graph cuts but is faster and allows its application to large 4D datasets. We applied our method on both cardiac 4D MRI and 4D CT datasets with promising results.

7962-89, Poster Session

Segmentation of liver and liver tumor for the Liver-Workbench

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Robust and efficient segmentation tools are important for the quantification of 3D liver and liver tumor volumes which can greatly help clinicians in clinical decision-making and treatment planning. A two-module image analysis procedure which integrates two novel semi-automatic algorithms has been developed to segment 3D liver and liver tumors from multi-detector computed tomography (MDCT) images. The first module is to segment the liver volume by deforming a 3D mesh model iteratively. In each iteration, before mesh deformation, the algorithm detects and avoids possible flippings which will cause the self-intersection of the mesh and then the undesired segmentation results. After flipping avoidance, Laplacian mesh deformation is performed with various constraints in geometry and shape smoothness. In the second module, the segmented liver volume is used as the ROI and liver tumors are segmented by exploring hybrid support vector machines (SVMs). First a rough tumor region is extracted using one-class SVMs with only tumor samples. These voxels recognized as non-tumor are selected according to certain similar criteria and re-samples. The extracted rough tumor voxels and those selected non-tumor voxels are used to train a two-class SVMs classifier to extract the final tumor region. The performance of the whole procedure was tested using 9 MDCT data sets and the results were promising: Eight liver volumes were successfully segmented out with minor to moderate errors. For live tumors segmentation, the median volume overlap error (VOE) and average symmetric surface distance (ASSD) to reference segmentation were 19.5% and 1.2 mm, respectively.

7962-90, Poster Session

Automatic detection, segmentation and characterization of retinal horizontal neurons in large-scale 3D confocal imagery

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Automatic analysis of neuronal structure from wide-field-of-view 3D image stacks of retinal neurons is essential for statistically characterizing neuronal abnormalities that may be causally related to neural malfunctions or may be early indicators for a variety of neuropathies. In this paper, we study classification of neuron fields in large-scale 3D confocal image stacks, a challenging neurobiological problem because of the low spatial resolution imagery and presence of intertwined dendrites from different neurons. We present a fully automated, four-step processing approach for neuron classification with respect to the morphological structure of their dendrites. In our approach, we first localize each individual soma in the image by using morphological operators and active contours. By using each soma position as a seed point, we automatically determine an appropriate threshold to segment dendrites of each neuron. We then use skeletonization and network analysis to generate the morphological structures of segmented dendrites, and shape-based features are extracted from network representations of each neuron to characterize the neuron. Based on qualitative results and quantitative comparisons, we show that we are able to automatically compute relevant features that clearly distinguish between normal and abnormal cases for postnatal day 6 (P6) horizontal neurons.

7962-91, Poster Session

3D segmentation of prostate ultrasound images using wavelet transform

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The current definitive diagnosis of prostate cancer is transrectal ultrasound (TRUS) guided biopsy. However, the current procedure is limited by using 2D biopsy tools to target 3D biopsy locations. This paper presents a new method for automatic segmentation of the prostate in three-dimensional transrectal ultrasound images, by extracting texture features and statistical matching of geometrical shape of the prostate. A set of Wavelet-based support vector machines (W-SVMs) are located and trained on different regions of the prostate surface. The WSVMs capture texture priors of ultrasound images for classification of prostate and non-prostate tissues in different zones around prostate boundary. In the segmentation procedure, these W-SVMs are trained in three sagittal, coronal, and transverse planes. The pre-trained W-SVMs are employed to tentatively label each voxel around the surface of the model as a prostate or non-prostate voxel by the texture matching. The labeled voxels in three planes after post-processing is overlaid on a prostate probability model. The probability prostate model is created using 10 segmented prostate data. Consequently, each voxel has four labels: sagittal, coronal, and transverse planes and one probability label. By defining a weight function for each labeling in each region, each voxel is labeled as prostate or non-prostate voxel. Experimental results by using real patient data show the good performance of the proposed model in segmenting the prostate from ultrasound images.

7962-92, Poster Session

Orientation estimation of anatomical structures in medical images for object recognition

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In [1], we presented a general method of model-based multi-object recognition to assist in segmentation (delineation) tasks. It exploits the pose relationship that can be encoded, via the concept of ball scale (b-scale) [2], between the binary training objects and their associated grey images. The goal was to place the model, in a single shot, close to the right pose (position, orientation, and scale) in a given image so that the model boundaries fall in the close vicinity of object boundaries in the image. Unlike position and scale parameters, we observe that orientation parameters require more attention when estimating the pose of the model as even small differences in orientation parameters can lead to inappropriate recognition. Motivated from the non-Euclidean nature of the pose information, we propose in this paper the use of non-Euclidean metrics to estimate orientation of the anatomical structures for more accurate recognition and segmentation. We statistically analyse and evaluate the following metrics for orientation estimation: Euclidean, Log-Euclidean, Root-Euclidean, Procrustes Size-and-Shape, and mean Hermitian metrics. The results show that mean Hermitian and Cholesky decomposition metrics provide more accurate orientation estimates than other Euclidean and non-Euclidean metrics.

7962-93, Poster Session

Automated detection of cone photoreceptors in high-resolution volume images of the retina

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Cone photoreceptors are specialized retinal cells that line the back of the eye and initiate vision by converting captured photons into an electrical signal. Cones consisting of photoreceptor cells with rods are responsible for color reception and acute vision, and packed densely near the macula. Cone density and packing structure are important indicators of cell health whose condition are known as one of the hallmarks for color vision related diseases such as achromatopsia and retinitis pigmentosa. Despite their biological and physiological significance, in vivo observation of cones has been limited due to insufficient imaging resolution. Recent applications of adaptive optics (AO) to ophthalmologic research led to ultra-high resolution imaging of the retina at microscopic scale, where the wavefront aberration is corrected to achieve high spatial fidelity. Combined with optical coherence tomography (OCT), AO-OCT technology have enabled to image the retina in 3D volume with high resolution, thus allowing in vivo investigation of the cones. The proposed method provides a fully automated cone photoreceptor detection algorithm with AO-OCT volumes acquired from several eccentricities. This study explores motion artifact removal, content-based spatial and spectral filter design, and spatial localization of cones. Human experts graded the detection accuracy to validate the performance of algorithm resulting in 99.4% precision and 95.5% recall.

7962-94, Poster Session

Local morphologic scale: application to segmenting tumor infiltrating lymphocytes in ovarian cancer TMAs

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The idea of a locally adaptive scale (e.g., generalized, tensor, and ball scale) has been previously introduced for facilitating a large number of image processing operations including filtering, intensity standardization, bias field correction, image registration, and segmentation. These scale notions are centered on the idea of associating a local descriptor with every spatial location. For instance, generalized scale represented the largest connected set associated with every image location, with all elements of the set satisfying some pre-defined homogeneity criterion. In this paper we present a framework for a novel local morphological scale (LMS) notion which associates with every spatial location in the image, a descriptor capturing the shape of the largest unimpeded neighborhood. This is a departure from previous scale formulations that were defined based on a locally connected set of pixels, all of which satisfied some pre-defined homogeneity criterion, or were constrained by some shape criterion. LMS yields a unique signature of local structure at every spatial location. LMS scenes thus constructed could be applied to a number of image processing applications, including image registration and segmentation. By characterizing the physical concept of fluid flow associated with particles emanating from a point of interest, we are able to define a local region corresponding to the catchment area created by the flow of these particles. Shape descriptors quantifying the morphology of this local catchment region are used to define LMS. These shape descriptors can be used in conjunction with supervised classifiers for scene segmentation and classification. By using a monte-carlo sampling technique, LMS is efficiently determined through parallelized computations. In this paper, we apply LMS to the specific problem of classifying regions of interest in Ovarian Cancer (OCa) histology images as either tumor or stroma. This approach is used to classify lymphocytes as either tumor infiltrating lymphocytes (TILs) or non-TILs; the presence of TILs serving as an important prognostic indicator. We present preliminary results on the tumor/stroma classification of 8,000 randomly selected locations of interest, across 11 images obtained from 6 patient studies. Our supervised learner, after generating features at 38 milliseconds a sample, was able to reach an Area Under the Curve (AUC) of 0.808.

7962-95, Poster Session

Brain tumour segmentation and tumour tissue classification based on multiple MR protocols

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Segmentation of brain tumours in Magnetic Resonance (MR) images and classification of the tumour tissue into vital, necrotic, and perifocal edematous areas is required in a variety of clinical applications. Manual delineation of the tumour tissue boundaries is a tedious and error-prone task, and the results are not reproducible. Furthermore, tissue classification mostly requires information of several MR protocols and contrasts. Here we present a nearly automatic segmentation and classification algorithm for brain tumour tissue working on a combination of T1 weighted contrast enhanced (T1CE) images and fluid attenuated inversion recovery (FLAIR) images. Both image types are included in MR brain tumour protocols that are used in clinical routine. The algorithm is based on a simple region growing technique, hence it is fast (ten seconds on a standard personal computer). The only required user interaction is a mouse click for providing the starting point. The region growing parameters are automatically adapted in the course of growing, and if a new maximum image intensity is found, the region growing is restarted. This makes the algorithm robust, i.e. independent of the given starting point in a certain capture range. Furthermore, we use a lossless coarse-to-fine approach, which, together with the automatic adaptation of the parameters, can avoid leakage of the region growing procedure. We tested our algorithm on 20 cases of human glioblastoma and meningioma. In the majority of the test cases we got satisfactory results.

7962-96, Poster Session

Ensemble framework for GBM brain tumor segmentation

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It is a challenging task to automatically segment glioblastoma multiforme (GBM) brain tumors on T1w post-contrast isotropic MR images. Recently, Liu et al. 1 developed a semi-automated system using fuzzy connectedness for computing the tumor volume that reduces the cost of manual annotation. In this study, we propose a framework for combining multiple segmentation results into a final ensemble one. The framework is evaluated on a dataset of 20 cases from a multi-center pharmaceutical drug trial and compared to the fuzzy connectedness method. Three individual methods were used in the framework: fuzzy connectedness, GrowCut, and voxel classification. The combination method is a confidence map averaging (CMA) method. The CMA method shows an improved performance on the ROC curve compared to the fuzzy connectedness method ($p < 0.001$). The CMA ensemble result is more robust compared to the three individual methods.

7962-97, Poster Session

Feature-driven model-based segmentation

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The accurate delineation of anatomical structures is required in many medical image analysis applications. One example is radiation therapy planning (RTP), where traditional manual delineation is tedious, labor intensive, and can require hours of clinician's valuable time. Majority of automated segmentation methods in RTP belong to either model-based or atlas-based approaches. One substantial limitation of model-based segmentation is that its accuracy may be restricted by the uncertainties in image content, specifically when segmenting low-contrast anatomical structures, e.g. soft tissue organs in computed tomography images. In this paper, we introduce a non-parametric feature enhancement filter which replaces raw intensity image data by a high level probabilistic map which guides the deformable model to reliably segment low-contrast regions. The method is evaluated by segmenting the submandibular and parotid glands in the head and neck region and comparing the results to manual segmentations in terms of the volume overlap. Quantitative results show that we are in overall good agreement with expert segmentations, achieving volume overlap of up to 80%. Qualitatively, we demonstrate that we are able to segment low-contrast regions, which otherwise are difficult to delineate with deformable models relying on distinct object boundaries from the original image data.

7962-98, Poster Session

Cell segmentation and splitting for histopathological image analysis

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Follicular Lymphoma (FL) is a cancer arising from the lymphatic system. Originating from follicle center B cells, FL is mainly comprised of centrocytes (usually middle-to-small sized cells) and centroblasts (relatively large malignant cells). According to the World Health Organization's recommendations, there are three grades of FL characterized by the number of centroblasts per high-power field (hpf) of area 0.159 mm2. In current practice, these cells are manually counted from ten representative fields of follicles. Several studies clearly demonstrate the poor reproducibility of this grading system with very low inter-reader agreement. Generally, in computer-based FL diagnosis, the cells (including the centroblast cells and the other types of cells) should be separated from each other so that the quantification of feature can be carried out on single cell for classification of cell types. In this study, we propose a pathological image segmentation algorithm, which separates the cells from the background and extra-cellular regions, based on supervised learning of a discriminant texture from a new color space. For evaluation, our method is compared with the state-of-the-art segmentation algorithms (graph-cut and superpixels). Empirical results show that our segmentation method achieves better performance than these popular methods. In addition, we also propose an iterative cell-splitting method based on radial symmetry and concave point detection. By combining with the above cell segmentation algorithm, the cell images are decomposed into background, extra-cellular regions, and the set of split single cells.

7962-99, Poster Session

Automatic ROI identification for fast liver tumor segmentation using graph-cuts

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The key challenge in tumor segmentation is to determine their exact location and volume. Difficulties arise because of low intensity boundaries, varying shapes and sizes. Furthermore, tumors can be located everywhere in the liver. Interactive segmentation methods seem to be the most appropriate (in terms of reliability and robustness) for this case. In this work, we use a graph-cut based method to interactively segment tumors. However, complexity of the underlying graphs is enormous for clinical 3D datasets. Therefore, we propose a method to identify automatically a region of interest using a coarse resolution image, which is then used to construct a reduced graph for final segmentation in the original image in full resolution using graph-cuts. We compared our results to ground truth segmentations done by experts. Our results suggest that accuracy is comparable to other approaches. The average overlap was 80%, while the average surface distance was 0.73 mm and the average maximum surface distance 5.314 mm.

7962-100, Poster Session

Simultaneous automatic detection of optic disc and fovea on fundus photographs

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We proposed an automated and simultaneous localization method for the optic disc and fovea on fundus photograph. An enhancement and correction step is introduced, which allows the detection result of one structure to facilitate the detection of the other one. In the first step of the method, a set of features is extracted from the color fundus image, and the relationship between the features and a distance variable is established during the training phase. For a test image, the same set of features is measured and the distance to the optic disc and fovea can be estimated using k-nearest-neighbor classification. A probability image with every pixel labeled a probability of within the optic disc or the fovea is generated. In the second step of the method, a second k-nearest-neighbor classification is applied on the probability image. Another set of features is extracted and trained. For a test image, detected high likelihood regions from the first step can be enhanced only if they satisfy the trained relationship. A set of 250 color fundus images from the left eye were used to train the system. Another set of 310 color fundus images were used to test the system. The correct rate for the optic disc is 93.6%. The correct rate for the fovea is 88.2%. This is a fully automatic method to detect the optic disc and fovea simultaneously with excellent performance. We are currently expanding validation on larger datasets.

7962-101, Poster Session

Supervised segmentation methods for the hippocampus in MR images

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This study compares three different types of fully automated supervised segmentation methods for segmentation of the hippocampus in MR images. Many of such supervised methods have been presented for various medical imaging applications, but comparison of the methods is obscured because of optimization for, and evaluation on, different data. We compare three implementations of atlas-based segmentation (ABS), active appearance model segmentation (AAMS) and k-nearest neighbor voxel classification (KNN).

All three methods are trained on 100 example images with manual segmentations of the right hippocampus, and applied to 100 different T1-weighted images from the same study.

Basic implementation of each of the three methods resulted in competitive segmentations, compared with methods currently reported in literature. AAMS and KNN are favorable in terms of computational costs, requiring only a fraction of the time needed for ABS. The high accuracy and low computational cost make KNN the most favorable method based on this study. AAMS achieves similar results as ABS in significantly less computation time.

Further improvements might be achieved by fusion of the presented techniques, either methodologically or by direct fusion of the segmentation results.

7962-102, Poster Session

Integrating an adaptive region based appearance model with a landmark free statistical shape model: application to prostate MRI segmentation

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In this paper we present a system for segmenting medical images using statistical shape models (SSM's) which is landmark free, fully 3D, and accurate. To overcome the limitations associated with previous 3D landmark-based SSM's, our system creates a levelset-based SSM which is trained using the distances to the object's surface.

Subsequently, an advanced statistical appearance model (SAM) is generated to model the object of interest.

This SAM is based on a series of statistical texture features calculated from each image, modeled by a Gaussian Mixture Model. Segmenting a new image requires a Bayesian classification of the voxels in the image, and optimally fitting the SSM so there is maximum agreement between the SAM and SSM. The SAM is then able to adaptively learn the statistics of the new image, after which the process repeats until convergence. We have tested our system on 36 T2-w, 3.0 Tesla, in vivo, endorectal prostate images. The results showed that our system achieves a Dice similarity coefficient of .84 ± .04, with a median Dice value of .86, which is comparable (and in most cases superior) to other state of the art prostate segmentation systems. Unlike most state of the art segmentation schemes, our scheme is fully automated requiring no user intervention. Overall, we have developed a novel method for integrating an adaptive appearance model with a landmark free shape model which can be used to segment structures with known shapes.

7962-103, Poster Session

Segmenting multiple overlapping objects via an integrated region and boundary based active contour incorporating shape priors: applications to histopathology

A. N. Sahirzeeshan, A. Madabhushi, Rutgers, The State Univ. of New Jersey (United States)

Active contours and active shape models have been widely employed in image segmentation. A major limitation of active contours, however, is in their inability to resolve boundaries. Multiple overlapping objects are typically segmented out as a single object. On the other hand, active shape models incur point correspondence issues due to the limitation provided by the use of points and are constrained in that they can usually only segment a single object. In this paper, we present a novel synergistic boundary and region-based active contour model that incorporates shape priors in a level set formulation. We demonstrate an application of these synergistic active contour models using multiple level sets to segment nuclear and glandular structures on digitized histopathology. Unlike previous related approaches, our model is able to resolve object overlap and separate occluded boundaries of multiple objects simultaneously. The energy functional of the active contour is comprised of three terms. The first term is based off the shape term, modeled off the object of interest, thereby constraining the deformation achievable by the active contour. The second boundary based term detects object boundaries from image gradients. The third term drives the shape prior and the active contour towards a homogeneous intensity region. Results of qualitative and quantitative evaluation of our model on 100 prostate and 14 breast cancer histology images reveals that our scheme easily outperforms traditional active contours and active shape models in resolving overlaps by accurately segmenting up to 92% of overlapping/occluded lymphocytes and lumens.

7962-104, Poster Session

Automatic three-dimensional rib centerline extraction from CT scans for enhanced visualization and anatomical context

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We present a complete automatic system to extract 3D centerlines of ribs from thoracic CT scans. Our rib centerline system determines the positional information for the rib cage consisting of extracted rib centerlines, spinal canal centerline, pairing and labeling of ribs. We show an application of this output to produce an enhanced visualization of the rib cage by the method of Kiraly et al., in which the ribs are digitally unfolded along their centerlines. The centerline extraction consists of three stages: (a) pre-trace processing for rib localization, (b) rib centerline tracing, and (c) post-trace processing to merge the rib traces. Then we classify ribs from non-ribs and determine anatomical rib labeling. Our novel centerline tracing technique uses the Random Walker algorithm to segment the structural boundary of the rib in successive 2D cross sections orthogonal to the longitudinal direction of the ribs. Along the rib the centerline is progressively traced using a 3D Kalman filter. The rib centerline extraction framework was evaluated on 149 CT datasets with varying slice spacing, dose, and under a variety of reconstruction kernels. The results of the evaluation are presented. The extraction takes approximately 20 seconds on a modern radiology workstation and performs robustly even in the presence of partial volume effects or rib pathologies such as bone metastases or fractures, making the system suitable for assisting clinicians in expediting routine rib reading for oncology and trauma applications.

7962-105, Poster Session

Segmentation of in vivo target prior to tracking

N. Masson, Ecole Nationale Supérieure de Physique de Strasbourg (France); P. Zanne, Ecole Nationale Supérieure de Physique de Strasbourg (France) and Ctr. National de la Recherche Scientifique (France); F. P. Nageotte, Ecole Nationale Supérieure de Physique de Strasbourg (France); M. de Mathelin, Ecole Nationale Supérieure de Physique de Strasbourg (France) and Ctr. National de la Recherche Scientifique (France)

Flexible endoscopes are used in many diagnostic and interventional procedures. Physiological motions may be very difficult to handle with such device, hence disturbing the physician in completing his task. One way of dealing with these motions is to have the endoscope following them on its own. To achieve such a goal one needs to motorize the flexible endoscope and to know accurately the position of the region of interest (target), in order to control the motors. To this purpose a tracking algorithm is used, which estimates the position of the target in the images acquired by the camera of the endoscope. But the tracking algorithm needs to be initialized correctly so as not to loose the target. The difficulty is that targets have many different characteristics and we have no prior knowledge about them. Besides we want the algorithm to be user friendly, particularly for the physicians, which means that no parameter has to be tuned even with completely different targets. The proposed algorithm computes a modified gradient image from first-order moments to obtain smooth edges and reduce the number of regions found during the next step. A watershed method is used to detect regions. Thanks to the previous processing of the image, most irrelevant regions will not be detected. Then a merging process is applied which results in a region corresponding to the target. From the border of this region we find a patch that will be used to initialize the tracking algorithm. Experimental results are promising.

7962-106, Poster Session

Stability based validation of cellular segmentation algorithms

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The gold standard of segmentation evaluation involves comparing segmentation outputs to manually obtained ground-truth. This assumes that the ground-truth images are accurate and representative of the entire image set. In applications such as image Cytometry where ground-truth delineation is tedious, only a handful of ground-truth images are used in practice. This violates the basic assumptions of ground-truth based validation. This paper describes a method of assessing the performance of segmentation algorithms without ground-truth images. Segmentation errors are either statistical or structural. Statistical errors reflect failure to account for random variations in pixel values while structural errors result from inadequate image description models. As statistical errors predominate image Cytometry, our method focuses on statistical stability assessment. For any image-algorithm pair, we obtain multiple perturbed variants of the image by applying slight linear blur. We segment the image and its variants with the algorithm and determine the match between the output from the image and the output from its variants, using multi-image DICE and Jaccard metrics. We establish the accuracy of the method in two ways. First, utilizing 48 realistic phantom images with known ground-truth and four different segmentation algorithms, we show that statistical validation and ground-truth validation scores correlate in over 96% of cases. Second, analyzing a commercial set of 6000 images, we find that the method reliably identifies good and bad segmentations. The statistical validation approach drastically reduces segmentation review effort and enables assessment of segmentation quality long after an algorithm has been deployed.

7962-107, Poster Session

Neural stem cell segmentation in phase contrast movies

S. U. Rigaud, IPAL International Mixed Research Unit UMI CNRS 2955 (Singapore) and Univ. of Pierre and Marie Curie (France); N. Lomenie, IPAL International Mixed research Unit UMI CNRS 2955 (Singapore) and Ctr. National de la Recherche Scientifique (France) and Univ. Paris Descartes (France)

Tracking and segmenting object in video is a well known field of research and very efficient methods exist. But these processes are not necessary adapted for biological images. In this purpose, we propose to test the Sigma-Delta motion filter, normally developed for security and surveillance camera, in order to track neural stem cells and their evolution over time, in a phase contrast video. The motion filter is based on a recursive spatio-temporal morphological operator called hybrid reconstruction. It allows robust and fast motion detection by estimating the static scene. After testing directly the filter, we obtain corrects results but we needed to adapt it to obtain better segmentation. We continue our testing by modifying it, only keeping the spatio-temporal morphological operator, and manage to obtain shorter background learning time and less sensibility from sudden background movement. And we used a post processing validation test using compacity in order to accept or discard bad segmentation. At the end we manage to shorter the background learning time and

7962-108, Poster Session

Boundary detection by linear programming with application to lung fields segmentation

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Medical image segmentation is typically used to locate boundaries of anatomical structures in images acquired by different modalities. As segmentation is of utmost importance for quantitative measurements and analyses of anatomical structures, tracking anatomical changes over time, building anatomical atlases and visualization of medical images, a huge amount of methods have been developed and tested on a wide range of applications in the past. Deformable or parametric shape models have been widely used for segmentation. A drawback of deformable model approaches it that they require initialization near the final solution. In this paper, we present a segmentation algorithm that incorporates prior knowledge and is composed of two steps. First, reference points on the boundary of an anatomical structure are found by linear programming incorporating prior knowledge. Second, paths between reference points, representing boundary segments, are searched for by optimal control. The segmentation method has been applied to chest radiographs from the publicly available SCR database.

7962-109, Poster Session

A liver segmentation approach in contrast-enhanced CT images with patient specific knowledge

A. Afifi, T. Nakaguchi, N. Tsumura, Chiba Univ. (Japan)

In this work, we propose a shape-based liver segmentation approach using a patient specific knowledge. In which, we exploit the relation between consequent slices in multi-slice CT images to update the shape template that initially determined by the user. Then, the updated shape template is integrated with the graph cut algorithm to segment the liver in each CT slice. The statistical parameters of the liver and non-liver tissues are initially determined according to the initial shape template and it is consequently updated from the nearby slices. The proposed approach does not require any prior training and it uses a single phase CT images; however, it is talented to deal with complex shape and intensity

variations. The proposed approach is evaluated on 20 CT images with different kinds of liver abnormalities, tumors and cysts, and it achieves an average volumetric overlap error of 6.4% compared to the manual segmentation.

7962-110, Poster Session

Multiple weak segmentors for strong mass segmentation in mammogram

Y. Zhang, N. Tomuro, J. D. Furst, D. S. Raicu, DePaul Univ. (United States)

Previous studies have shown that image enhancement greatly affects the quality of mass segmentation in mammograms. However, because of various variability factors including the image contrast ranges and patients' breast density levels, it is difficult to select an/one optimal image enhancement which can fit all images for mass segmentation.

To adapt to those variability factors, this paper proposes to build multiple weak segmentors for identifying a mass contour for a suspicious mass region (ROI) in mammogram. In this study, we first apply various parameters of the image enhancement functions to a single ROI image to generate several enhanced images. Then we compute the energy descriptor (one of Haralick descriptors) of each pixel in an enhanced ROI, and create energy texture images. Next, using an edge-based segmentation method, a mass contour is detected from each energy texture image. We call each of such segmentations a "weak segmentor" because none of them is committed as the final segmentation. Finally, we select the one with the highest overlapping ratio as the final segmentation (i.e., the "strong segmentor") for the image.

In our experiment, 81.8% of the images in the dataset were successfully segmented by a strong segmentor (vs. 34.2% for the original ROI images), and it was higher than that of any one of the five weak segmentors we tested (average 69.3%). This result indicates that using multiple weak segmentors is an effective method to generate a strong mass segmentation for mammograms.

7962-111, Poster Session

A framework for automated coronary artery tracking of low axial resolution multislice CT images

J. Wu, E. Lewis, Univ. of Surrey (United Kingdom); G. Ferns, Keele Univ. (United Kingdom); J. W. Giles, Conquest Hospital (United Kingdom)

Low axial resolution data such as multi-slice CT(MSCT) used for coronary artery disease screening must balance the potential loss in image clarity, detail and partial volume effects with the benefits to the patient such as faster acquisition time leading to lower dose exposure. In addition, tracking of the coronary arteries can aid the location of objects contained within, thus helping to differentiate them from similar in appearance, difficult to discern neighboring regions.

A fully automated system has been developed to segment and track the main coronary arteries and visualize the results. Automated heart isolation is carried out for each slice of an MSCT image using active contour methods. Ascending aorta and artery root segmentation is performed using a combination of active contours, morphological operators and geometric analysis of coronary anatomy to provide a starting point for vessel tracking. Artery tracking and backtracking employs analysis of vessel position combined with segmented region shape analysis to obtain artery paths. Robust, accurate threshold parameters are calculated for segmentation utilizing Gaussian Mixture Model fitting and analysis.

The low axial resolution of our MSCT data sets, in combination with poor image clarity and noise presented the greatest challenge. Classification techniques such as shape analysis have been utilized to good effect and our results to date have shown that such deficiencies in the data can be overcome, further promoting the positive benefits to patients.

7962-112, Poster Session

3D segmentation of medical volume image using hybrid level set method

M. Lee, W. Cho, S. Kim, S. Kim, Chonnam National Univ. (Korea, Republic of)

We present a new segmentation method using the level set framework in the medical images. The method has conducted by using the curve evolution model based on the geometric variation principle and the level set theory. And the speed function in the level set approach is consisted of hybrid combination of three integral measures that are derived by the theory of calculus of variation. They are called the robust alignment term, the active region term, and the smoothing term. These measures can help to detect the precise location of the target object and prevent the boundary leakage problem. The proposed method has been tested on the synthetic image and various medical volume images with normal tissue and the tumor region to evaluate its performance visually and qualitatively. The experimental results show that an effectiveness and superior performance of our method is relatively excellent when it is compared with traditional approaches.

7962-113, Poster Session

Brain MRI segmentation and lesion detection using generalized Gaussian and Rician modeling

X. Wu, Univ. of Houston (United States); S. Bricq, C. Collet, LSIIT, Univ. de Strasbourg (France)

Purpose: mixed noise modeling method so as to segment the brain MRI images and to detect lesion is proposed.

Method: We have exploited alternative distributions other than Gaussian to fit the likelihood between model and data corresponding to White Matter (WM), Gray Matter (GM) and cerebro-spinal fluid(CRF). The probability density of the noise related coefficients of CRF is modeled as random variables of a Rician distribution and Generalized Gaussian distribution is used to fit data of WM and GM. In addition, a Gaussian copula regression model is applied to determine the joint distribution with given non-Gaussian marginal distributions.

Results: We will present in this paper promising results showing that, in a multimodal segmentation-detection scheme, the proposed model fits better with the data and increases lesion detection rate.

New or breakthrough work to be presented: Mixture noise (Rice and Generalized Gaussian).

This work has never been published.

7962-114, Poster Session

Robust method for extracting the pulmonary vascular trees from 3D MDCT images

W. E. Higgins, P. Taeprasartsit, The Pennsylvania State Univ. (United States)

Segmentation of pulmonary blood vessels from three-dimensional (3D) multi-detector CT (MDCT) images is important for pulmonary applications. This work presents a method for extracting the vascular trees of the pulmonary arteries and veins, applicable to both contrast-enhanced and unenhanced 3D MDCT image data. The method finds 2D elliptical cross-sections and evaluates agreement of these cross-sections in consecutive slices to find likely cross-sections. It next employs morphological multiscale analysis to separate vessels from adjoining airway walls. The method then tracks the center of the likely cross-sections to connect them to the pulmonary vessels in the mediastinum and forms connected vascular trees spanning both lungs. A ground-

truth study indicates that the method was able to detect on the order of 98% of the vessel branches having diameter greater or equal 3.0 mm. The extracted vascular trees can be utilized for the guidance of safe bronchoscopic biopsy.

7962-115, Poster Session

A computerized scheme for localization of vertebral bodies on body CT scans

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The multi-detector row computed tomography (MDCT) method can potentially be used for quantitative analysis of osteoporosis with higher accuracy and precision than that provided by conventional 2-D methods. To develop a computer-assisted scheme for analyzing vertebral geometry using body CT images is desirable. Aim of this study was to design a computerized scheme for localization of vertebral bodies on body CT images. Our new scheme was proposed according to the following concepts: (1) CT images reformation based on the center line of the spinal canal to visually remove the spinal curvature; (2) To use the information on the relative position between ribs and vertebral bodies; (3) To build a simple model based on the contour of the vertebral bodies on CT sections; (4) Localization of individual vertebral bodies by use of a template matching technique. The proposed scheme was applied to 104 CT cases and its performance was assessed using the Hausdorff distance. The average Hausdorff distance of T2-L5 by use of learning models with 100 samples was 4.3 mm. On the other side, the average Hausdorff distance with 10 samples was 5.1 mm. On the basis of the results of our assessments, we validated that the proposed scheme could provide the location of individual vertebral bodies. Therefore, the proposed scheme may be useful to design a computer-based application which analyses vertebral geometry on body CT images.

7962-116, Poster Session

Unsupervised segmentation of ultrasound images by fusion of spatio-frequential textural features

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Image segmentation plays an important role in both qualitative and quantitative analysis of medical ultrasound images. However, due to their poor resolution and strong speckle noise, segmenting objects from this imaging modality remains a challenging task and may not be satisfactory with traditional image segmentation methods. To this end, this paper presents a simple, reliable, and conceptually different segmentation technique to locate and extract bone contours from ultrasound images. Instead of considering a new elaborate (texture) segmentation model specifically adapted for the ultrasound images, our technique proposes to fuse (i.e. efficiently combine) several segmentation maps associated with simpler segmentation models in order to get a final reliable and accurate segmentation result. More precisely, our segmentation model aims at fusing several K-means clustering results, each one exploiting, as simple cues, a set of complementary textural features, either spatial or frequential. Eligible models include the gray-level co-occurrence matrix, the re-quantized histogram, the Gabor filter bank, and local DCT coefficients. The experiments reported in this paper demonstrate the efficiency and illustrate all the potential of this segmentation approach.

7962-117, Poster Session

Applying nonlinear band expansion and nonnegative matrix underapproximation for unsupervised segmentation of liver from multiphase CT image

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A methodology is proposed for contrast enhanced unsupervised segmentation of liver from two-dimensional multi-phase CT image. The multi-phase CT image is represented by a linear mixture model, whereupon each single-phase CT image is modeled as linear mixture of spatial distributions of the organs present in the image. The methodology exploits concentration and spatial diversities between organs present in the image and consists of nonlinear dimensionality expansion followed by matrix factorization that relies on sparseness between spatial distributions of organs. Dimensionality expansion increases concentration diversity (contrast) between organs. The methodology is demonstrated on an experimental three-phase CT image of a liver.

7962-118, Poster Session

Automatic segmentation of chromatographic images for region of interest delineation

A. M. Mendonça, Univ. do Porto (Portugal) and Instituto de Engenharia Biomédica (Portugal); A. V. Sousa, Univ. do Porto (Portugal) and Instituto Superior de Engenharia do Porto (Portugal); M. C. Sá-Miranda, Univ. do Porto (Portugal); A. C. Campilho, Instituto de Engenharia Biomédica (Portugal) and Univ. do Porto (Portugal)

This paper describes a segmentation method for automating the delineation of the region of interest (ROI) in chromatographic images, thus allowing the definition of the image area that contains the fundamental information for further processing while excluding the frame of the chromatographic plate that does not contain relevant data for disease identification. This is the first component of a screening tool for Fabry disease, which will be based on the automatic analysis of the chromatographic patterns extracted from the image ROI.

Image segmentation is performed in two phases. In the first phase, an unsupervised learning method is used for classifying image pixels into three classes: frame, ROI or unknown. The unknown pixels usually correspond to image regions with intensity characteristics differing from their neighbourhood, namely due to chromatographic development or plate digitalization. For this purpose, an Expectation-Maximization (EM) clustering algorithm was selected using as input the two first PCA components extracted from the measured chromatic features that demonstrated the highest discrimination potential between the image frame and the ROI.

As the pixels of the unknown class appear as image areas mainly embedded into one of the other classes, in the second phase the average and standard deviation of the distance of class members to the image boundary are used for deciding which class the unknown pixels belong to.

The binary image resulting from segmentation is post-processed using morphological operators to obtain the final ROI rectangular area. This methodology was successfully evaluated in 41 digital images of chromatographic plates.

7962-119, Poster Session

A nonparametric segmentation method based on structural information using level sets

Y. Zhu, Syracuse Univ. (United States); S. Cheng, The Univ. of Oklahoma - Tulsa (United States); A. L. Goel, Syracuse Univ. (United States)

Segmentation plays an important role in medical imaging, a precise segmentation can significantly improve the accuracy of object detection and localization. Level set based model is robust in image segmentation, but the parameters of level set function are usually decided by empirical method, which discourages its application in medical area, because medical images are various and the users may not be familiar with parameters setting of level set method. In this paper, we present an automatic segmentation method based on variational level set formulation. This method is formulated by statistical measures and solved by using the Euler-Lagrange equation. The segmentation criteria of our method rely on structural similarities of the image, which are luminance, contrast, and correlation coefficients. These criteria are formulated into an energy function to maximize the structural difference between object and background in segmentation. The energy function is solved and implemented by using variational level set method. Unlike prevalent level set methods, the segmentation parameters of our approach are automatically decided by structural information of the image and updated during iteration, so our model is nonparametric. Moreover, our approach does not necessitate any training, nor any a priori assumption about probability density functions of statistical inference. Furthermore, our method is region-based without using gradients, and the parameters in our method are updated according to image information, so our method can significantly reduce computation costs in its numerical implementation. The segmentation results have shown that our method adequately captures the structural differences between object and background during segmentation.

7962-120, Poster Session

Simultaneous image segmentation and medial structure estimation: application to 2D and 3D vessel tree extraction

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We propose a variational approach which combines automatic segmentation and medial structure extraction in a single computationally efficient algorithm. In this paper, we apply our approach to the analysis of vessels in 2D X-ray angiography and 3D X-ray rotational angiography of the brain. Other variational methods proposed in the literature encode the medial structure of vessel trees as a skeleton with associated vessel radii. In contrast, our method provides a dense smooth level set map which sign provides the segmentation. The ridges of this map define the segmented regions skeleton. The differential structure of the smooth map (in particular the Hessian) allows the discrimination between tubular and other structures. In 3D, both circular and non-circular tubular cross-sections and tubular branching can be handled conveniently. This algorithm allows accurate segmentation of complex vessel structures. It also provides key tools for extracting anatomically labeled vessel tree graphs and for dealing with challenging issues like kissing vessel discrimination and separation of entangled 3D vessel trees.

7962-121, Poster Session

A unified framework for concurrent detection of anatomical landmarks for medical image understanding

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Anatomical point landmarks as most primitive anatomical knowledge are useful for medical image understanding. In this study, we construct a unified framework for automated anatomical landmark detection. Our framework includes appearance-based initial candidate detection and MadaBoost-based classification. The appearance models for the candidate detection represent gray-level statistical variations in cubic ROI around landmarks and are built based on results of PCA (Principal Component Analysis) for transformed ROI of sample data by employing generative learning. The candidates of a landmark are defined as local minima of eigen-residue in matching with the appearance model for the landmark. Classifier ensembles used in our framework consist of weak classifiers of thresholding functions for local image features including principal scores and Haar-like features. Principal score is calculated by projecting appearance vector extracted from ROI onto single dimension eigen-space with over 1 % accumulation ratio. In our experiments with 24 data sets of body trunk CT, the average sensitivity in detecting candidates of 22 landmarks was 95.0 % and 13 landmarks were detected with 100 % sensitivity. Based on the classifier, FP candidates in initial detection part (average amount of FP / case is 2713.9 per landmark) was reduced to 28.6 at 95.0 % sensitivity. The results showed that the method has enough performance for our subsequent procedure for selecting final candidates by a MAP estimator based on inter-landmark distances.

7962-122, Poster Session

Automatic classification for mammogram backgrounds based on bi-rads complexity definition and on a multi content analysis framework

J. Wu, Univ. de Technologie Compiègne (France); Q. J. A. Besnehard, C. Marchessoux, Barco N.V. (Belgium)

Clinical studies for the validation of new medical imaging devices require hundreds of images. An important step in creating and tuning the study protocol is the classification of images into “difficult” and “easy” cases. This consists of classifying the image based on features like the complexity of the background, the visibility of the disease (lesions). Therefore an automatic medical background classification tool for mammograms would help for such clinical studies. This classification tool is based on a multi-content analysis framework (MCA) which was firstly developed to recognize image content of computer screen shots. With the implementation of new texture features and a defined breast density scale, the MCA framework is able to automatically classify digital mammograms with a satisfying accuracy. BI-RADS (Breast Imaging Reporting Data System) density scale is used for grouping the mammograms, which standardizes the mammography reporting terminology and assessment and recommendation categories. Selected features are input into a decision tree classification scheme in MCA framework, which is the so called “weak classifier” (any classifier with a global error rate below 50%). With the AdaBoost iteration algorithm, these “weak classifiers” are combined into a “strong classifier” (a classifier with a low global error rate) for classifying one category. The results of classification for one “strong classifier” show the good accuracy with the high true positive rates. For the four categories the results are: TP=90.38%, TN=67.88%, FP=32.12% and FN =9.62%.

7962-123, Poster Session

Foibles, follies, and fusion: assessment of statistical label fusion techniques for web-based collaborations using minimal training

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Labeling or parcellation of structures of interest on magnetic resonance imaging (MRI) is essential in quantifying and characterizing correlation with numerous clinically relevant conditions. The use of statistical methods with automated techniques or complete data sets from several different raters has been proposed to simultaneously estimate both rater reliability and true labels. An extension to these statistical based methodologies was proposed that allowed for missing labels, repeated labels and training trials. Herein, we present and demonstrate the viability of these statistical based methodologies using real world data contributed by minimally trained human raters. The consistency of the statistical estimates, the accuracy compared to the individual observations and the variability of both the estimates and the individual observations with respect to the number of labels are discussed. It is demonstrated that the Gaussian based statistical approach using the previously presented extensions successfully performs label fusion in a variety of contexts using data from online (Internet-based) collaborations among minimally trained raters. This first successful demonstration of a statistically based approach using “wild-type” data opens numerous possibilities for very large scale efforts in collaboration. Extension and generalization of these technologies for new application spaces will certainly present fascinating areas for continuing research.

7962-124, Poster Session

Automatic tissue classification for high-resolution breast CT images based on bilateral filtering

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Breast tissue classification can provide quantitative measurements for breast composition, density and tissue distribution with respective to ages for diagnosis. In this study, we present an automatic classification method to classify high-resolution breast CT images. The breast is classified into into skin, fat and glandular tissue. First, we use a multiscale bilateral filter to reduce the noise and keep edges on the images. As skin and glandular tissue have similar CT values in breast CT images, we use morphologic operations to get the mask of the skin based on information of its position. Second, we use a modified fuzzy C-mean classification method twice, one for the skin and the other for the fatty and glandular tissue. We compared our classified results with manually segmented results. We use Dice overlap ratios to evaluate our classification method. Our method has been tested with noisy images. The overlap ratios for glandular tissue were above 94.7% for data from five patients. Evaluation results showed that our method is robust and accurate.

7962-125, Poster Session

Automated cell analysis tool for a genome-wide RNAi screen with support vector machine based supervised learning

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RNAi-based high-throughput microscopy screens have become an important tool in biological sciences in order to decrypt mostly unknown biological functions of human genes. However, manual analysis is impossible for such screens since the amount of image data sets can often be in the hundred thousands. Reliable automated tools are thus required to analyse the fluorescence microscopy image data sets usually containing two or more reaction channels. The herein presented image analysis tool is designed to analyse an RNAi screen investigating the intracellular trafficking and targeting of acylated Src kinases. In this specific screen, a data set consists of three reaction channels and the investigated cells can appear in different phenotypes. The main issue of the image processing task is an automatic cell segmentation which has to be robust and accurate for all different phenotypes and a successive phenotype classification. The cell segmentation is done in two steps by segmenting the cell nuclei first and then using a classifier-enhanced region growing on basis of the cell nuclei to segment the cells. The classification of the cells is realized by a support vector machine which has to be trained manually using supervised learning. Furthermore, the tool is brightness invariant allowing different staining quality and it provides a quality control that copes with typical defects during preparation and acquisition. A first version of the tool has already been successfully applied for an RNAi-screen containing three hundred thousand image data sets and the SVM extended version is designed for additional screens.

7962-126, Poster Session

Automatic detection of region of interests in mammographic images

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Automatic detection of region of interest (ROI) in mammographic images serves as the very first step towards fully automatic mammographic image analysis and diagnosis. In this paper, we study using machine learning approaches for this task. Specifically, we apply the boosting-based framework for ROI detection. Due to the very limited number of training samples, we boost the training set by including more ROIs that are close to the annotated ones and decompose the original images to randomly generate negative samples. Based on these training samples, the Adaboost algorithm in combination with Haar wavelets is utilized in this task to learn a ROI detector. The learned detector usually generates a large amount of true and false positives. A confidence score for each candidate detection result is calculated for further localization. We first merge the detected ROIs by combining tightly overlapped detected candidate ROIs. Then, by using the fact only one ROI is needed for each input image, we design three different strategies to eliminate false positives according to confidence scores. The proposed method is evaluated on a dataset containing 28 galactographic images. Despite the challenges of the task, our method produces very promising results obtaining a detection rate of 96.43%.

7962-127, Poster Session

Plexiform neurofibroma tissue classification

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Plexiform Neurofibroma (PN) is a major complication of NeuroFibromatosis-1 (NF1), a common genetic disease that involves the nerve system. PNs are peripheral nerve sheath tumors extending along the length of the nerve in various parts of the body. Treatment decision is based on tumor volume assessment using MRI, which is currently time consuming and error prone, with limited semi-automatic segmentation support. We present in this paper a new method for the segmentation and tumor mass quantification of PN from STIR MRI scans. The method utilizes a user-based initial delineation of the tumor area in a single

slice to automatically detect the PN lesions in the entire image, while utilizing the connectivity nature of the tumor. The user involvement in the segmentation process is minimal, so our method has the potential to successfully become part of the clinical workflow. Experimental results on seven datasets yield a mean volume overlap difference of 25% as compared to manual segmentation by expert radiologist with a mean computation and interaction time of 12 minutes vs. over an hour for manually annotation.

7962-128, Poster Session

A novel classification method based on histogram equalization and membership function

Y. Peng, Shanghai Univ. (China); C. Shen, G. Zhang, L. Wang, East China Normal Univ. (China)

We propose a novel method for medical image classification based on histogram equalization and membership function. Our aim is to classify the image as several classes based on a prior knowledge from physicians. For every point, we calculate its membership function, which is the probability that it belongs to each class. The point is finally labeled as the class with the highest value of membership function. The classification is reduced to a minimization problem of a functional whose arguments are membership functions. Three novelties compared with traditional membership methods are in our paper. First, histogram equalization, which is a pre-process in order to improve the image quality, is adopted to the input image to enhance the image contrast. The histogram equalized image is added as an extra band of the input, i.e. the previous grey image now becomes a two-band image. Thus the amount of information that can be used in classification increases, which will be helpful for further process. Second, unconstrained functional is used. Constraints are added in the literature since memberships functions need to be bounded and with sum equal to one, which is avoided here by variable substitution. Third, several techniques are used to fasten the computation. Intermediate variables are introduced so that a big complicated functional is separated as four relatively easy functionals, each of them can be solved with fast speed. Fast algorithm of Bregman method is also used in the iteration. The experimental result of ventricle shows the validity of this approach.

7962-129, Poster Session

Automatic 3D kidney segmentation based on shape constrained GC-OAAM

X. Chen, R. M. Summers, J. Yao, National Institutes of Health (United States)

The kidney could be classified into three main tissue types: renal cortex, renal medulla and renal pelvis (or collecting system). Different dysfunction of renal tissue types may cause different kidney diseases. Therefore, accurate and efficient segmentation of kidney into different tissue types plays a very important role in the clinical research. In this paper, we propose an automatic 3D kidney segmentation method which segments the kidney into three different tissue types: renal cortex, medulla and pelvis. The proposed method synergistically combines active appearance model (AAM), liver wire (LW) and graph cut (GC) methods, GC-OAAM for short. Our method consists of two main steps. First, a pseudo 3D segmentation method is employed for kidney initialization in which the segmentation is performed slice-by-slice via multi-object oriented active appearance model (OAAM) method. An improved iterative model refinement algorithm is proposed for the AAM optimization, which synergistically combines the AAM and LW method. And a multi-object strategy is applied to help the object initialization. The 3D model constraints are applied to the initialization result. Second, the object shape information generated from the initialization step is integrated into the GC cost computation. A multi-label GC method is used to segment the kidney into cortex, medulla and pelvis. The proposed method was tested on 19 clinical arterial phase CT data sets. The preliminary results showed the feasibility and efficiency of the proposed method.

7962-130, Poster Session

A new steerable pressure force for parametric deformable models

J. Kong, L. Cooper, A. Sharma, T. Kurc, D. J. Brat, J. H. Saltz, Emory Univ. (United States)

Active contour models have been widely used in various image analysis applications. Despite their usefulness, there are problems limiting their utility, such as capture range, concavity conformation, and convergence rate. This paper presents a new pressure-like force that not only improves contour convergence rate, but also encourages contours to conform to concave regions. Unlike the traditional pressure force, this new force does not require users' input for the force direction and is steerable according to the image content. Better convergence rate as well as force normalization consistency of this new force are presented when compared with those of the gradient vector flow force field on synthetic images. Accuracies of these two methods are compared against the manual markups on a set of cardiac MRI images. Moreover, results on a MRI image smoothed at different levels demonstrate the robustness of this new force to noise.

7962-131, Poster Session

Toward a parts-based approach to sub-cortical brain structure parsing

D. Gagneja, Indian Institute of Technology, Kharagpur (India) and Univ. at Buffalo (United States); C. Xiong, J. J. Corso, Univ. at Buffalo (United States)

The automatic localization and segmentation, or parsing, of neuroanatomical brain structures is a key step in many neuroscience tasks. However, the inherent variability in these brain structures and their appearance continues to challenge medical image processing methods. The state of the art primarily relies upon local voxel-based morphometry, Markov random fields, and probabilistic atlas based approaches, which limits the ability to explicitly capture the parts-based structure inherent in the brain. We propose a method that defines a principled parts-based representation of the sub-cortical brain structures. Our method is based on the pictorial structures model and jointly models the appearance of each part as well as the layout of the parts as a whole. Inference is cast as a maximum a posteriori problem and solved in a steepest-descent manner. Experimental results on a 28-case data set demonstrate high accuracy of our method and substantiate our claim that there is significant promise in a parts-based approach to modeling medical imaging structures.

7962-132, Poster Session

Region based level set segmentation of the outer wall of the carotid bifurcation in CTA

D. V. Vukadinovic, T. van Walsum, R. Manniesing, S. Rozie, A. van der Lugt, W. J. Niessen, Erasmus MC (Netherlands)

This paper presents a level set based segmentation method for outer vessel wall of the carotid artery in CTA. The method is being used to segment the outer vessel wall of the carotid artery around the bifurcation area where most of the atherosclerotic plaque is collected. It utilizes a GentleBoost classification framework that classifies pixels as inside or outside the vessel wall. Similarly, GentleBoost is used to classify calcium objects as true or false ones. The combined result of both classifications is used to construct a speed function for region based level set segmentation of the outer vessel wall. Dilated automatically

segmented lumen is used to initialize the level set. The method has been evaluated on 80 datasets for which manually annotated data was available as reference. The average Dice similarity of the outer vessel wall segmentation was 92 % and standard deviation was 0.03.

7962-133, Poster Session

Implicit medial representation for vessel segmentation

G. Pizaine, Philips Healthcare (France) and Telecom ParisTech (France); E. D. Angelini, I. Bloch, Telecom ParisTech (France); S. Makram Ebeid, Philips Healthcare (France)

In the context of mathematical modeling of complex vessel tree structures with deformable models, we present a novel level set formulation to evolve both the vessel surface and its centerline. The implicit function is computed as the convolution of a geometric primitive, representing the centerline, with localized kernels of continuously-varying scales allowing accurate estimation of the vessel width. The centerline itself is derived as the characteristic function of an underlying signed medialness function, to enforce a tubular shape for the segmented object, and evolves under shape and medialness constraints. Given a set of initial medial loci and radii, this representation first allows for simultaneous recovery of the vessels centerlines and radii, thus enabling surface reconstruction. Secondly, due to the topological adaptivity of the level set segmentation setting, it can handle tree-like structures and bifurcations without additional junction detection schemes nor user inputs. We discuss the shape parameters involved, their tuning and their influence on the control of the segmented shapes, and we present some segmentation results on synthetic and clinical image data.

7962-134, Poster Session

A study on automated anatomical labeling to arteries concerning with colon from 3D abdominal CT images

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This paper presents an automated anatomical labeling method of arteries are extracted from contrasted 3D CT images based on multi class AdaBoost. In abdominal surgery, understanding of blood vasculature related to a target organ such as the colon is very important. The anatomical structure of blood vessels needs to be understood by computers in a system supporting diagnosis vasculature understanding. The proposed method obtains a tree structure of arteries from the vascular area, and calculate feature values of each arterial branch. Then, candidate names of arteries are computed by classifiers that output artery names. After assigning candidate names of arteries, determine final artery names are relabeled by a global optimization process. In the experiments using 14 cases of abdominal arteries extracted from 3D abdominal CT images, the average recall and precision rates of the proposed method were 93.3% and 87.9%, respectively.

7962-135, Poster Session

Direction-dependent level set segmentation of cerebrovascular structures

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Exact cerebrovascular segmentations based on high resolution 3D anatomical datasets are required for many clinical applications. A general problem of most vessel segmentation methods is the insufficient delineation of small vessels, which are often represented by rather low intensities and high surface curvatures. This paper describes an improved direction-dependent level set approach for the cerebrovascular segmentation. The proposed method utilizes the direction information of the eigenvectors computed by vesselness filters for adjusting the weights of the internal energy depending on the location. The basic idea of this is to weight the internal energy lower in case the gradient of the level set is comparable to the direction of the eigenvector extracted by the vesselness filter. A quantitative evaluation of the proposed method based on three clinical Time-of-Flight MRA datasets with available manual segmentations using the Tanimoto coefficient showed that a mean improvement compared to the initial segmentation of 0.081 is achieved, while the corresponding level set segmentation without integration of direction information does not lead to satisfying results. In summary, the proposed method enables an improved delineation of small vessels, especially of those represented by low intensities and high surface curvatures.

7962-136, Poster Session

Completely automated multiresolution edge snapper (CAMES): a new technique for an accurate carotid ultrasound IMT measurement and its validation on a multi-institutional database

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Aim of this paper is the description of a novel and completely automated technique for carotid artery segmentation and intima-media thickness (IMT) measurement.

The completely automated multi-resolution edge snapper (CAMES) technique consists of two stages: (1) automated multi-resolution carotid recognition based on convolutions of higher order Gaussian derivative kernel with down-sampled fine-to-coarse images; and (2) automated segmentation of carotid wall's lumen-intima (LI) and media-adventitia (MA) interface based on multi-resolution first absolute moment edge operator and IMT measurement. Three-hundred multi-institutional B-Mode longitudinal carotid images were used to validate the system. The ground-truth was the average manual segmentation of three experts. CAMES was benchmarked against a previously automated technique based on an integrated approach.

The mean segmentation errors ± SD using CAMES were 0.081 ± 0.099 mm for the LI interface and 0.082 ± 0.197 mm for the MA interface.

CAMES showed a reduction in segmentation errors for LI and MA interfaces by 8% and 42%. CAMES was very robust and accurate: it correctly processed 100% of the images.

The combination of multi-resolution recognition and segmentation led to an automated, low-complexity, real-time, and accurate technique for carotid IMT measurement. Validation on a multi-institutional dataset demonstrated the robustness of the technique, which can constitute a valid IMT measurement tool for large image databases.

7962-137, Poster Session

Evaluation of blood vessel detection methods

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Detecting blood vessels in medical images is a commonly addressed but challenging problem. There is thus a need to evaluate the performance of different detection algorithms quantitatively. The standard approach compares the detected vessel map with a ground-truth vessel mask. For detection methods that give a response monotonically related to vessel probability at each pixel/voxel, results are often presented as receiver operator characteristic (ROC) curves, obtained by applying a series of thresholds to the response image(s); otherwise total error rate or the kappa statistic may be used. We argue that this approach is uninformative, because the results tend to be dominated by the detection of large vessels and fail to capture adequately whether or not finer, lower contrast vessels have been detected successfully.

We describe four different strategies for evaluating vessel detection, and compare the ROC curves obtained when they are used to assess the performance of a new algorithm for detecting blood vessels in retinograms. The detection method - which uses a dual-tree complex wavelet representation and random forest classification - is evaluated using the public domain DRIVE database of retinograms, which provides a ground truth mask for each vessel tree. The four evaluation strategies are: a) the standard approach; b) comparing detected and ground-truth centre-lines; c) and d) hybrid strategies that define true positives similarly to (b) and false positives similarly to (a). We show that (c) and (d) provide performance estimates that depend on the length of vessel detected, irrespective of width, whilst (a) over-estimates and (b) under-estimates performance.

7962-138, Poster Session

Automatic segmentation and diameter measurement of coronary artery vessels

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This work presents a hybrid method for 2D artery vessel segmentation and diameter measurement in X-Ray angiograms. The proposed method is novel in that tracking-based and model-based approaches are combined. A robust and efficient tracking template, the “annular template”, is devised for vessel tracking. It can readily be applied on X-Ray angiograms without any preprocessing. Starting from an initial tracking point given by the user the tracking algorithm iteratively repositions the annular template and thereby detects the vessel boundaries and possible bifurcations. With a user selected end point the tracking process results in a set of points that describes the contour and topology of an artery vessel segment between the initial and end points. A “boundary correction and interpolation” operation refines the extracted points which initialize the Snakes algorithm. Boundary correction adjusts the points to ensure that they lie on the vessel segment of interest. Boundary interpolation adds more points, so that there are sufficiently many points for the Snakes algorithm to generate a smooth and accurate vessel segmentation. After the application of Snakes the resulting points are sequentially connected to represent the vessel contour. Then, the diameters are measured along the extracted vessel contour. The segmentation and measurement results are compared with manually extracted and measured vessel segments. The average Precision, Recall and Jaccard Index of 21 vessel samples are 91.5%, 92.1% and 84.9%, respectively. Compared with ground truth measurements of diameters the average relative error is 8.2%, and the average absolute error is 1.13 pixels.

7962-139, Poster Session

Liver fat quantification using fast kVp-switching dual energy CT

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Nonalcoholic steatohepatitis (NASH) describes the clinical disease whereby patients are found to have increased fat deposition in the liver but lack a history of the well-proven association of alcohol use. It is a disease increasing in prevalence in the US and is correlated with obesity and type 2 diabetes mellitus. Since liver biopsy is the current primary method for diagnosis for NASH, a noninvasive method that can reliably diagnose and monitor treatment for this disease would be useful. Fast kVp-switched dual-energy CT can reliably compute monochromatic energy x-ray images having improved accuracy of tissue discrimination. We describe our pilot efforts to apply fast-switched DECT to locate and quantify fat deposition in the liver. Simulation software was used to create a phantom with a set of concentric rings, each composed of fat and soft tissue in different relative amounts using appropriate NIST values. Monte Carlo 80 and 140 kVp x-ray projections were acquired and monochromatic images of the phantom were reconstructed. Results demonstrated the sensitivity of fast-switched DECT to the presence of fat and its ability to distinguish fat from soft tissue. Additionally, actual patient (liver) data were acquired using fast-switched DECT and monochromatic x-ray images at 70 and 140 keV were reconstructed. Two algorithms, one employing HU differences and the other multi-material decomposition, were applied to these datasets for liver fat quantification. Preliminary results demonstrate a tissue sensitivity that appears sufficient to quantify fat content with a degree of accuracy as may be needed for clinical assessment of NASH.

7962-140, Poster Session

Robust biological parametric mapping: an improved technique for multimodal brain image analysis

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Mapping the quantitative relationship between structure and function in the human brain is an important and challenging problem. Numerous volumetric, surface, regions of interest and voxelwise image processing techniques have been developed to statistically assess potential correlations between imaging and non-imaging metrics. Recently, biological parametric mapping has extended the widely popular statistical parametric approach to enable application of the general linear model to multiple image modalities (both for regressors and regressands) along with scalar valued observations. This approach offers great promise for direct, voxelwise assessment of structural and functional relationships with multiple imaging modalities. However, as presented, the biological parametric mapping approach is not robust to outliers and may lead to invalid inferences (e.g., artifactual low p-values) due to slight mis-registration or variation in anatomy between subjects. To enable widespread application of this approach, we introduce robust regression and robust inference in the neuroimaging context of application of the general linear model. Through simulation and empirical studies, we demonstrate that our robust approach reduces sensitivity to outliers without substantial degradation in power. The robust approach and associated software package provides a reliable way to quantitatively assess voxelwise correlations between structural and functional neuroimaging modalities.

7962-141, Poster Session

Automatic assessment of ultrasound image usability

J. Stoll, Siemens Healthcare (United States); L. Valente, G. D. Funka-Lea, Siemens Corporate Research (United States)

We present a novel and efficient approach for evaluating the quality of ultrasound images. Image acquisition is sensitive to skin contact and transducer orientation and requires both time and technical skill to be done properly. Images commonly suffer degradation from acoustic shadows and signal attenuation, which present as regions of low signal intensity masking anatomical details and making the images partly or totally unusable. As ultrasound image acquisition and analysis becomes increasingly automated, it is beneficial to also automate the estimation of image quality. Towards this end, we present an algorithm that classifies regions of an image as usable or un-usable. This analysis is done intuitively by human operators and precedes the identification of image content. Example applications of this algorithm include improved compounding of free-hand 3D ultrasound volumes by eliminating unusable data and improved automatic feature detection by limiting detection to only usable areas. The algorithm operates in two steps. First, it classifies the image into bright areas, likely to have image content, and dark areas, likely to have no content. Second, it classifies the dark areas into unusable (i.e. due to shadowing and/or signal loss) and usable (i.e. anatomically accurate dark regions, such as with a blood vessel) sub-areas. The classification considers several factors, including statistical information, gradient intensity and geometric properties such as shape and relative position. Relative weighting of factors was obtained through training of a Support Vector Machine. Classification results for both human and phantom images are presented and compared to manual classifications. This method achieves 91% sensitivity and 91% specificity for usable regions of human scans.

7962-142, Poster Session

An image-guided tool to prevent hospital acquired infections

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Hospital acquired infections (HAI) represents the fourth leading cause of death in the United States, and claims hundreds of thousands of lives annually in the rest of the world. This paper presents a novel low-cost mobile device -- called Stery-Hand -- that helps to avoid HAI by improving hand hygiene control through providing an objective evaluation of the quality of hand disinfection. The general idea is to use the Stery-Hand intuitively: having performed hand washing with a soap mixed with UV reflective powder, the skin appears brighter under UV light on the sterile surfaces. Washed hands are inserted into the Stery-Hand box, where a picture is taken under UV lighting. Automated image processing algorithms are employed in three steps to evaluate the quality of hand washing. First, the contour of the hand is extracted in order to distinguish the hand from the background. Next, a semi-supervised clustering algorithm classifies the pixels of the hand into three groups-corresponding to clean, partially clean and dirty areas. The clustering algorithm is derived from the histogram-based quick fuzzy c-means approach, using a priori information extracted from reference images, evaluated by experts. Finally, the identified areas are adjusted to suppress shading effects, and quantified in order to give a verdict on hand disinfection quality. The proposed methodology was validated through tests using hundreds of images recorded in our laboratory. The proposed system was found robust and accurate, producing correct estimation for over 98% of the test cases. Stery-Hand may be employed in general practice, and it may also serve educational purposes.

7962-143, Poster Session

Propagating uncertainties in statistical model based shape prediction

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This paper addresses the question of accuracy assessment and confidence regions estimation in statistical model based shape prediction. Shape prediction consists in estimating an organ's outline based on a partial observation, due e.g. to limited field of view or poorly contrasted images, and generally requires a statistical model. However, such predictions can be impaired by several sources of uncertainty, in particular the presence of noise in the observations, limited correlations between the predictors and the shape to predict, as well as limitations of the statistical shape model - in particular the number of available training samples. The novelty of the proposed framework is to take these into account to derive confidence regions around the predicted shape. Our method relies on the construction of two coupled statistical shape models, one for the predictors and one for the unseen parts, and exploits the correlations between them assuming a joint Gaussian distribution. Limitations of the models are taken into account by optimizing the prediction scheme and evaluating the shape reconstruction error through cross-validation. An application to the prediction of the surface of the human proximal tibia given the shape of the distal femur is proposed, using a database of 184 samples. An evaluation is proposed, which indicates that reliable confidence regions could be estimated. Potential applications are reconstructive surgery, supporting e.g. implant design and selection, or targeting in functional neurosurgery when the structure to be treated cannot be directly visualized and needs to be inferred from nearby visible structures.

7962-144, Poster Session

Shape model training for concurrent localization of the left and right knee

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An automatic approach for training of suitable models for the Generalized Hough Transform (GHT) is presented. The shape of the target object is learned directly from training images, incorporating variability in pose and scale. To make the model more robust and representative for the target object, an individual weight is estimated for each model point using a discriminative approach. These weights will then be employed in the voting procedure of the GHT, increasing the impact of important points on the localization result. The proposed procedure is extended here with a new error measure and a revised point weight training to allow the integration of several target objects into one model. Mutual parts of the target objects will thereby obtain larger weights, while the model will still be representative for all targets.

The method is applied to the localization of knee joints in long-leg radiographs. Quantitative comparison of the new approach with the separate localization of right and left knee showed good results concerning localization precision and performance.

7962-145, Poster Session

Whole vertebral bone segmentation method with a statistical intensity-shape model based approach

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(Purpose) In this study, we has been developed an automatic segmentation algorithm for the vertebrae in human body CT images. Especially we focused on constructing and utilizing 4 different statistical intensity-shape combined models for the cervical, upper / lower thoracic and lumbar vertebrae, respectively. (Methods) Two previously reported methods were combined: a deformable model-based rough segmentation method and a statistical shape-intensity model-based fine segmentation method. The former is used as a pre-process to detect the position and orientation of each vertebra, which determines the initial condition of the latter fine segmentation method. The fine segmentation method needs some prior knowledge on both the intensities (the shape-regularized intensity image) and the shapes (the deformation vector field image for the shape-regularization) of the objects. After PCA analysis of such shape-intensity expressions obtained from training image sets, vertebrae were parametrically modeled as a linear combination of the principal component vectors. The segmentation of each target vertebra was performed as fitting of this parametric model to the target image by maximum a posteriori estimation, combined with the geodesic active contour method. (Result) The rough segmentation was successful in 6 cases and only partially failed in 4 cases (2 in the cervical area and 2 in the lumbo-sacral). In the precise segmentation, the mean error distances were 2.078, 1.416, 0.777, 0.939 mm for cervical, upper and lower thoracic, lumbar spines, respectively. (Conclusion) Our automatic segmentation algorithm for the vertebrae in human body CT images showed a fair result for for cervical, thoracic and lumbar vertebrae.

7962-146, Poster Session

Detecting hippocampal shape changes in Alzheimer's disease using statistical shape models

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The hippocampus is affected at an early stage in the development of Alzheimer's disease (AD). Using brain Magnetic Resonance (MR) images, we can investigate the effect of AD on the morphology of the hippocampus. Statistical shape models (SSM) are usually used to describe and model the hippocampal shape variations among the population. We use the shape variation from SSM as features to classify AD from normal control cases (NC). Conventional SSM uses principal component analysis (PCA) to compute the modes of variations among the population. Although these modes are representative of variations within the training data, they are not necessarily discriminant on labelled data. In this study, a Hotelling's T2 test is used to qualify the landmarks which can be used for PCA. The resulting variation modes are used as predictors of AD from NC. The discrimination ability of these predictors is evaluated in terms of their classification performances using support vector machines (SVM). Features extracted from the SSM model built on the reduced subset of landmarks lead to an improved discrimination between the groups.

7962-147, Poster Session

Classification of mathematics deficiency using shape and scale analysis of 3D brain structures

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We investigate the use of a recent technique for shape analysis of brain substructures in identifying learning disabilities in third-grade children. This Riemannian technique provides a quantification of differences in shapes of parameterized surfaces, using a distance that is invariant to rigid motions and re-parameterizations. Additionally, it provides an optimal registration of points across surfaces for improved matching and comparisons. We utilize an efficient gradient based method to obtain the optimal re-parameterizations of surfaces. In this study we consider 20 different substructures in human brain and correlate the differences in their shapes with abnormalities manifested in deficiency of mathematical skills in 106 subjects. The selection of these structures is motivated in part by the past links between their shapes and cognitive skills, albeit in broader contexts. We have studied the use of both individual substructures and multiple structures jointly for disease classification. Using a leave-one-out classifier, we obtained a 62.3% classification rate based on the shape of the left hippocampus. The use of multiple structures resulted in an improved classification rate of 71.4%.

7962-148, Poster Session

A decision support scheme for vertebral geometry on body CT scans

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To obtain the improved knowledge on the bone quality, there is a great attention on vertebral geometry in anatomy. Aim of this study was to design a decision support scheme for vertebral geometry. The proposed scheme consists of four parts: (1) Automated extraction of bone; (2) Generation of median plane image of spine; (3) Detection of vertebrae; (4) Quantification of vertebral depth, width, cross-sectional area (CSA), and bone mineral density (BMD). The proposed scheme was applied to 10 CT cases, and compared to the manual tracking made by an anatomic expert. Mean differences of depth, width, CSA, and BMD were 1.2 mm, 2.7 mm, 71.7 mm2, and 7.3 mg/cm3, respectively. We found that moderate or high correlations of vertebral geometries between our scheme and the manual tracking ($r > 0.72$). However, measurements of our scheme were slightly-smaller than those of the manual tracking. These experimental results suggested that our scheme could contribute to investigate vertebral geometries on CT scans.

7962-149, Poster Session

A joint model for boundaries of multiple anatomical parts

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The use of joint shape analysis of multiple anatomical parts is a promising area of research with applications in medical diagnostics, growth evaluations, and disease characterizations. In this paper, we consider several features (shapes, orientations, scales, and locations) associated with anatomical parts and develop probability models that capture interactions between these features. The shape models are based on elastic shape analysis of continuous boundary curves. The proposed

model is a second order model that considers principal coefficients in tangent spaces of joint manifolds as multivariate normal random variables. Additionally, it models interactions across objects using area-interaction processes. Using 10 observations of four anatomical parts: caudate, hippocampus, putamen and thalamus, on one side of brain, we first estimate the model parameters and then generate random samples from them using Metropolis-Hastings algorithm. The plausibility of these random samples validates the proposed models.

7962-150, Poster Session

Global-to-local, shape-based, real and virtual landmarks for shape modeling by recursive boundary subdivision

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Landmark based statistical object modeling techniques, such as Active Shape Modeling, have proven useful in medical image analysis. Identification of the same homologous set of points in a training set of object shapes is the most crucial step in ASM, which has encountered challenges such as (C1) defining and characterizing landmarks; (C2) ensuring homology; (C3) generalizing to n > 2 dimensions; (C4) achieving practical computations. In this paper, we propose a novel global-to-local strategy that attempts to address C3 and C4 directly and works in nD. The 2D version starts from two initial corresponding points determined in all training shapes via a method [3], and subsequently by subdividing the shapes into connected boundary segments by a line determined by these points. A shape analysis method [3] is applied on each segment to determine a landmark on the segment. This point introduces more pairs of points, the lines defined by which are used to further subdivide the boundary segments. This recursive boundary subdivision (RBS) process continues simultaneously on all training shapes, maintaining synchrony of the level of recursion, and thereby keeping correspondence among generated points automatically by the correspondence of the homologous shape segments in all training shapes. The process terminates when no subdividing lines are left to be considered that indicate (as per method [3]) that a point can be selected on the associated segment. Examples of [3] and [3] are presented based on (a) distance; (b) Principal Component Analysis (PCA); and (c) the novel concept of virtual landmarks.

7962-151, Poster Session

Automatic cortical thickness analysis on rodent brain

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Localized difference in the cortex is one of the most useful morphometric traits in human and animal brain studies. There are many tools and methods already developed to automatically measure and analyze cortical thickness for human brain. However, these tools cannot be directly applied to mouse brains due to the different scales; even adult rodent brains are 50 to 100 times smaller than humans.

This paper describes an algorithm for automatically measuring the cortical thickness of mouse and rat brains. The algorithm consists of three steps: segmentation, thickness measurement, and statistical analysis among experimental groups. The segmentation step provides the neo-cortex separation from other brain structures and thus is a preprocessing step for the thickness measurement. In the thickness measurement step, the thickness is computed by solving a Laplacian PDE and a transport equation. The Laplacian PDE first creates streamlines as an analogy of cortical columns; the transport equation computes the length of the streamlines. The result is stored as a thickness map over the neo-cortex surface.

For the statistical analysis, it is important to sample thickness at corresponding points. This is achieved by particle correspondence algorithm which minimizes entropy between dynamically moving sample points called particles. Since the computational cost of the correspondence algorithm may limit the number of corresponding points, we use thin-plate spline based interpolation to increase the number of corresponding sample points.

As a driving application, we measured the thickness difference for the effect of adolescent intermittent ethanol exposed rats that persist into adulthood and performed t-test between the two groups. We found significant regions in both hemispheres.

7962-152, Poster Session

Statistical modeling of the vascular tree

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Automatic examination of medical images is increasingly important due to the rising amount of data. Therefore automated methods are required which combine anatomical knowledge and robust segmentation to examine the structure of interest. Our proposed method generates a statistical atlas of the vascular tree which is based on 56 anatomical landmarks and 70 unbranched vessel sections. An underlying graph representation provides required anatomical topology, semantics and defines existing landmarks with attached vessel sections. The atlas was build using 86 semi-automatically generated geometric models of various body regions ranging from carotid arteries to the lower legs. The geometric models contain vessel centerlines as well as orthogonal cross-sections in equidistant intervals whereas the vessel contour has the form of a polygon path. After affine registration with axis-dependent scaling which minimizes mean square distance between corresponding points, the models were merged to form the statistical atlas. Subsequently, the atlas can be mapped to unseen images based on a small subset of landmarks. Among other information this approach provides probability distributions for the location of additional landmarks, vessel-specific geometric properties including shape, expected radii and branching points. The applications of this statistical model include model-based extraction of the vascular tree which greatly benefits from vessel-specific geometry description and variation ranges. Additionally, the level of interaction with the geometric model through anatomical names is significantly more user friendly for physicians. Furthermore, the statistical model can be applied as a basis for computer aided diagnosis systems as indicator for pathologically deformed vessels.

7962-153, Poster Session

Motion tracking of left ventricle and coronaries in 4D CTA

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In this paper, we present a novel approach for simultaneous motion tracking of left ventricle and coronary arteries from cardiac Computed Tomography Angiography(CTA) images. We first use the multi-scale vesselness filter proposed by Frangi et al to enhance vessels in the cardiac CTA images. The vessel centrelines are then extracted as

the minimal cost path from the enhanced images. The centrelines at end-diastolic (ED) are used as prior input for the motion tracking. All the other centrelines are used to evaluate the accuracy of the motion tracking. To segment the left ventricle automatically, we perform three levels of registration using the cardiac atlas obtained from MR images. The cardiac motion is derived from cardiac CTA sequences by using local-phase incorporated non-rigid registration. The CTA image at each time frame is registered to the ED frame by maximising the proposed cost function and following a serial propagation scheme. Once the images have been aligned, a dynamic motion model of the left ventricle can be obtained by applying the computed free-form deformations to the segmented left ventricle at ED phase. Similar propagation method also applies to the coronary arteries. To validate the accuracy of the motion model we compare the actual position of the coronaries and left ventricle in each time frame with the predicted ones as estimated from the proposed tracking method.

7962-154, Poster Session

Three-dimensional kinematic estimation of mobile-bearing total knee arthroplasty from x-ray fluoroscopic images

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To achieve 3D kinematic analysis of total knee arthroplasty (TKA), 2D/3D registration techniques, which use X-ray fluoroscopic images and computer-aided design (CAD) model of the knee implant, have attracted attention in recent years. These techniques could provide information regarding the movement of radiopaque femoral and tibial components but could not provide information of radiolucent polyethylene insert, because the insert silhouette on X-ray image did not appear clearly. Therefore, it was difficult to obtain 3D kinemaitcs of polyethylene insert, particularly mobile-bearing insert that move on the tibial component. This study presents a technique and the accuracy for 3D kinematic analysis of mobile-bearing insert in TKA using X-ray fluoroscopy, and finally performs clinical applications. For a 3D pose estimation technique of the mobile-bearing insert in TKA using X-ray fluoroscopy, tantalum beads and CAD model with its beads are utilized, and the 3D pose of the insert model is estimated using a feature-based 2D/3D registration technique. In order to validate the accuracy of the present technique, experiments including computer simulation test were performed. The results showed the pose estimation accuracy was sufficient for analyzing mobile-bearing TKA kinematics (the RMS error: about 1.0 mm, 1.0 degree). In the clinical applications, seven patients with mobile-bearing TKA in deep knee bending motion were studied and analyzed. Consequently, present technique enables us to better understand mobile-bearing TKA kinematics, and this type of evaluation was thought to be helpful for improving implant design and optimizing TKA surgical techniques.

7962-155, Poster Session

An iterative particle filter approach for respiratory motion estimation in nuclear medicine imaging

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The continual improvement in spatial resolution of Nuclear Medicine (NM) scanners has made accurate compensation of patient motion increasingly important. A major source of corrupting motion in NM acquisition is due to respiration. Therefore a particle filter (PF) approach has been proposed as a powerful method for motion correction in NM. The probabilistic view of the system in the PF is seen as an advantage that considers the complexity and uncertainties in estimating respiratory motion. Previous tests using XCAT has shown the possibility of estimating unseen organ configuration using training data that only consist of a single respiratory cycle. This paper augments application specific adaptation methods that have been implemented for better PF estimates with an iterative model update step. Preliminary results show that errors are further reduced to an extent and such improvements will be advantageous for the PF to cope with more realistic and complex applications.

7962-156, Poster Session

SLIMMER: SLice MRI Motion Estimation and Reconstruction tool for studies of fetal anatomy

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We describe a free software tool which combines a set of algorithms that provide a framework for building 3D volumetric images of regions of moving anatomy using multiple fast multi-slice MRI studies. It is specifically motivated by the clinical application of unsedated fetal brain imaging, which has emerged as an important area for image analysis. The tool reads multiple DICOM image stacks acquired in any angulation into a consistent patient coordinate frame and allows the user to select regions to be locally motion corrected. It combines algorithms for slice motion estimation, relative slice bias field correction and 3D volume reconstruction from multiple scattered slice stacks. The tool is built onto the RView (http://rview.colin-studholme.net) medical image display software and allows the user to inspect slice stacks, and apply both stack and slice level motion estimation that incorporates temporal constraints based on slice timing and interleave information read from the DICOM data. Following motion estimation an algorithm for relative bias correction provides the user with the ability to remove artifacts arising from the motion of the local anatomy relative to the imaging coils. Full 3D visualization of the slice stacks and individual slice orientations is provided to assist in evaluating the quality of the motion correction and final image reconstruction. The tool has been evaluated on a range of clinical data acquired on GE, Siemens and Philips MRI scanners.

7962-158, Poster Session

Development of an automated processing method to detect still timing of cardiac motion for coronary magnetic resonance angiography

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Whole-heart coronary magnetic resonance angiography (WH-MRA) is useful noninvasive examination. The data acquisition is performed during very short still timing in each cardiac motion cycle, and therefore in order to obtain the better image quality, it is important to select the adequate still timing. However, since the current available selection method is only manual one using visual comparison of cine MRI images with different phases, the selected timings are often incorrect and its reproducibility is not enough. We developed an automated selection method to detect the best still timing for the WH-MRA and compared the automated method with conventional manual one. Cine MRI was used for analysis. Each of pixel in images were processed with Fourier transform in cardiac phase direction. After processed data were given high pass filter processing, using invert Fourier transform. Cine images with high-speed image were obtained. To apply threshold processing, it is possible to select the still timing. In 10 healthy volunteers, we took WH-MRA and assessed curved planar reformation (CPR) image quality on a 4-point scale (1=excellent,

2=good, 3=fair, 4=poor). Mean automated CPR image quality and manual one were 4.2±0.38(RCA), 4.1±0.44(LAD), 3.9±0.52(LCX) and 4.1±0.42(RCA), 4.1±0.24(LAD), 3.2±0.35(LCX), only LCX($p<0.05$) and the other ($p>0.05$). Automated one could be to detect the still timing and more accurate than using visual selection. As a result, image quality was improved. This automated selection method contributes to scan coronary MRA semi-automatically in future.

7962-159, Poster Session

Shape anisotropy: tensor distance to anisotropy measure

Y. T. Weldeselassie, S. El-Hilo, S. M. Atkins, Simon Fraser Univ. (Canada)

Fractional anisotropy (FA), defined as the distance of a diffusion tensor from its closest isotropic tensor, has been extensively studied as quantitative anisotropy measures for diffusion tensor magnetic resonance images (DT-MRI). It has been used to reveal the white matter of brain images, as guiding feature for seeding and stopping in fiber tractography and for the diagnosis and assessment of degenerative brain diseases. Despite its extensive use in DT-MRI community, however, not much attention has been given to the mathematical correctness of its derivation from diffusion tensors which is achieved using Euclidean dot product in 9D space. But, recent progress in DT-MRI have shown that the space of diffusion tensors does not form a Euclidean vector space and thus Euclidean dot product is not appropriate for tensors. In this paper, we propose a novel and robust rotationally invariant diffusion anisotropy measure derived using appropriate tensor distance measures. We demonstrate qualitatively that our new anisotropy measure reveals superior white matter profile of DT-MR brain images and analytically show that it has a higher signal to noise ratio than FA.

7962-160, Poster Session

Scalable brain network construction on white matter fibers

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DTI offers a unique opportunity to characterize the structural connectivity of the human brain non-invasively by tracing white matter fiber tracts. Whole brain tractography studies routinely generate up to half million tracts per brain, which serves as edges in an extremely large 3D graph with up to half million edges. Currently there is no agreed-upon method for constructing the brain structural network graphs out of large number of white matter tracts. In this paper, we present a scalable iterative framework called the epsilon-neighbor method for building a network graph and apply it to testing abnormal connectivity in autism.

The epsilon-neighbor construction is motivated by the Rips complex of point cloud data, which has been used to characterize the topology of the point cloud data. The Rips complex is a graph constructed by connecting two data points if they are within specific distance. The problem of the Rips complex is that given n data points, it exactly produce a graph with n nodes so the resulting graph becomes very complicated when n becomes large. Unlike the Rips complex, the epsilon-neighbor method does not use every data points in constructing a graph so it significantly reduce the complexity of data. Further, while the point cloud data does not have any hidden topological constraint, the two end points of white matter fibers are connected so we are actually dealing with paired point cloud data. So the epsilon-neighbor construction is different than building the Rips complex while offer substantial computational advantage.

7962-161, Poster Session

Comparison between fourth and second order DT-MR image segmentations

S. El-Hilo, Y. T. Weldeselassie, S. M. Atkins, Simon Fraser Univ. (Canada)

A 2nd-order tensor is usually used to describe the diffusion of water for each voxel within a Diffusion tensor magnetic resonance imaging (DT-MRI) volume. However, a 2nd-order tensor approximation fails to accurately represent complex local tissue structures such as crossing fibers. Therefore, higher order tensors are used to represent more complex diffusivity profiles. In this work we propose a novel method to apply the random walker method to segment 4th-order tensor data. The approach proposed, takes advantage of all information provided by the tensors by using suitable dissimilarity tensor distance metrics. The distance metrics used are Log-Euclidean for second order tensors and normalized L2 distance for fourth order tensors. The segmentation is carried out on a weighted graph that represents the image where, the tensors are the nodes and the edge weights are computed using the dissimilarity tensor distance metrics. The advantages of performing segmentation on higher order tensor data is clearly demonstrated using synthetic crossing fibers where the 2nd order DTI model fails to segment such data. Application of our method to segment the corpus callosum of real human brain DT-MR data also qualitatively demonstrates the superiority of using the 4th order tensor model for segmentation of DT-MR images.

7962-162, Poster Session

DT-MR image segmentation using random walker algorithm

S. El-Hilo, Y. T. Weldeselassie, S. M. Atkins, Simon Fraser Univ. (Canada)

Image segmentation can be described as a method of separating an image into regions of interest, such as separating an object from the background. Many image segmentation methods have been proposed, each with its own strengths and weaknesses. The random walker image segmentation technique has been applied extensively to scalar images and has demonstrated robust results. In this work we propose a novel method to apply the random walker method to segmenting non-scalar diffusion tensor magnetic resonance imaging (DT-MRI) data. Moreover, a non-parametric probability density model is incorporated to provide estimates of the regional distributions enabling the random walker method to successfully segment disconnected objects. The proposed approach utilizes all the information provided by the tensors by using suitable dissimilarity tensor distance metrics. The method uses hard constraints for the segmentation provided interactively by the user, such that certain tensors are labeled as object or background. Then, a graph structure is created with the tensors representing the nodes and edge weights are computed using the dissimilarity tensor distance metrics. The distance metrics used are the Log-Euclidean and the J-divergence. The results of the segmentations using the two different dissimilarity metrics are compared and evaluated. Applying the approach to both synthetic and real DT-MRI data yields segmentations that are both robust and qualitatively accurate.

7962-163, Poster Session

Effect of regularization parameter and scan time on crossing fibers with constrained compressed sensing

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Diffusion tensor imaging (DTI) is an MR imaging technique that uses a set of diffusion weighted measurements in order to determine the water diffusion tensor at each voxel. In DTI, a single dominant fiber orientation is calculated at each measured voxel, even if multiple populations of fibers are present within this voxel. A new approach called Crossing Fiber Angular Resolution of Intra-voxel structure (CFARI) for processing diffusion weighted magnetic resonance data has been recently introduced. Based on compressed sensing, CFARI is able to resolve intra-voxel structure from limited number of measurements, but its performance as a function of the scan and algorithm parameters is poorly understood at present. This paper describes simulation experiments to help understand CFARI performance tradeoffs as a function of the data signal-to-noise ratio and the algorithm regularization parameter. In the compressed sensing criterion, the choice of the regularization parameter beta is critical. If beta is too small, then the solution is the conventional least squares solution, while if beta is too large then the solution is identically zero. The correct selection of beta turns out to be data dependent, which means that it is also spatially varying. In this paper, simulations using two random tensors with different diffusivities having the same fractional anisotropy but with different principle eigenvalues are carried out. Results reveal that for a fixed scan time, acquisition of repeated measurements can improve CFARI performance and that a spatially variable, data adaptive regularization parameter is beneficial in stabilizing results.

7962-164, Poster Session

A new metric to measure shape differences in fMRI activity

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We present a novel shape metric for quantification of shape differences between the activations obtained from independent component analysis (ICA) of group functional magnetic resonance imaging (fMRI) data comprising of several subjects. This metric is utilized to measure the difference in shapes of the activation regions obtained from different subjects within a group (healthy controls or patients). The parameters comprising the metric are computed for each pixel on the outermost contour (edge) of an activation region for each slice. These parameters are in the form of (r,) pairs that can be interpreted as the length and orientation of a vector originating from the Centroid of activation region to the pixel belonging to the boundary contour. Using this information we extract five features that quantify the shape difference between the two shapes under observation and combine them in to an empirically weighted metric. The two test shapes may be selected as activation maps from two different subjects or as activation from any subject and the aggregate activation map from group ICA. Another possible application is to compare various fMRI denoising methods that add to the distortion of shape of true activation regions. We present shape comparisons between a few commonly used fMRI denoising algorithms obtained from analysis of simulated data sets. In addition to the above results, we also address some interesting special cases such as when two or more activation contours are present in a single slice and present potential solutions for estimating the shape metric. Our results show that this metric has utility in creating a better understanding of the variability in brain activity among different groups of subjects performing the same task.

7962-165, Poster Session

Fast computation of functional networks from fMRI activity: a multiplatform comparison

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The traditional approach to analyze functional magnetic resonance imaging data has been to utilize individual voxel-based approaches, such as the Generalized Linear Model (GLM). With this approach, statistical differences are measured as a voxel responds to varying experimental conditions. Though this approach has yielded valuable insights into brain function, it has been shown to be limited in characterizing more complex brain interactions such as those present in the diagnosis of mental conditions such as schizophrenia [1]. In contrast, functional networks constructed from the same fMRI data have shown the power to discriminate more subtle differences in brain states between subjects and tasks they perform [1,2]. In functional networks, the time-series data in fMRI scans is converted to a graph notation, where an edge is drawn between a pair of voxels that have highly correlated activity. The edge can be made directional based on information carried in the computation of delayed correlation [2].

However, one of the challenges of the functional network approach is that it requires a significant amount of computation, as pair-wise delayed correlations need to be computed between every pair of voxels in the brain. This poses a computational bottleneck. In order to overcome this bottleneck, we propose to utilize parallel programming techniques on multiple low-cost platforms. We investigate the performance of our parallel technique on a GPU platform, consisting of the NVIDIA chip, and two multi-core CPU platforms, consisting of Power-7 and Intel chips.

Our results show that a speedup of 100X is achievable with the NVIDIA CUDA GPU platform over single-threaded execution. However, in order to achieve this, considerable effort has to be expended in figuring out the appropriate mapping of the problem to texture memory and registers, and the determining the optimum configuration of the number of threads (512 in this case), which has to be obtained after an exhaustive manual search. We are able to obtain a reasonable speedup of 30X by using the multi-core CPU platforms with significantly less programming effort and tuning. Our experience suggests that though GPUs may be suitable for very specific computations, multi-core CPUs offer a viable alternative due to their ease of programming [3]. This experience should prove useful to practitioners looking for ways to exploit parallelization to solve image processing problems in the domain of fMRI imaging.

References

1. “Predictive Network Models of Schizophrenia”, G.A. Cecchi, I. Rish, J-L. Martinot, M. Plaze, J-B. Poline, B. Thyreau and B. Thirion, NIPS 2009.

2. “Identifying directed links in large scale functional networks: application to brain fMRI”, G.A. Cecchi, A.R. Rao, M.V. Centeno, M. Baliki, A.V. Apkarian & D.R. Chialvo, BMC Cell Biology 2007, 8(Suppl 1):S5.

3. “Believe It or Not! Multi-core CPUs can Match GPU Performance for a FLOP-Intensive Application!”, R. Bordawekar, U. Bondhugula, and A. R. Rao. To appear in Parallel Architectures and Compilation Technology (PACT), September 2010.

7962-166, Poster Session

Detector defect correction of medical images on graphics processors

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The ever increasing complexity and power dissipation of computer architectures in the last decade blazed the trail for more power efficient parallel architectures.

Hence, such architectures like field-programmable gate arrays

(FPGAs) and particular graphics cards attained great interest and are consequently adopted for parallel execution of many number crunching loop programs from fields like image processing or linear algebra.

However, there is little effort to deploy barely computational, but memory intensive applications to graphics hardware. This paper considers a memory intensive detector defect correction pipeline for medical imaging with strict latency requirements. The image pipeline compensates for different effects caused by the detector during exposure of X-ray images and calculates parameters to control the subsequent dosage. So far, dedicated hardware setups with special processors like DSPs were used for such critical processing. We show that this is today feasible with commodity graphics hardware.

Using CUDA as programming model, it is demonstrated that the detector defect correction pipeline consisting of more than ten algorithms is significantly accelerated and that a speedup of 20x can be achieved on NVIDIA's Quadro FX 5800 compared to our reference implementation. For deployment in a streaming application with steadily new incoming data, it is shown that the memory transfer overhead of successive images to the graphics card memory is reduced by 83% using double buffering.

7962-167, Poster Session

Modeling of the rhodopsin bleaching with variational analysis of retinal images

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This paper discusses a variational method of processing the scanning laser ophthalmoscope(cSLO) image sequences in the context of extracting the local rhodopsin density and modeling the bleaching kinetics. This work supports the characterization and detection of early pathological changes in clinical retinal data. Our goals include providing automated tools for tracing early pathological changes over time, in particular rhodopsin density variations and local lesion progression.

Aside from helping to distinguish between healthy and possibly pathological regions, information about the bleaching parameters allows to separate and classify certain elements in the retinal image and may be utilized to refine the output of the edge-detection based method of the microvessel detection.

Our computational approach is a variational technique that approximates measured cSLO image sets optimally within the range of the bleaching model. The characterizing parameters of the approximating curves are computed locally and their spatial changes reflect variations in bleaching kinetics and hence changes in the local rhodopsin density. We estimate the local correlation between computed model parameters to visualize the spatial model dynamics and to evaluate the consistency of the data and the bleaching model.

Spatial and temporal denoising techniques are analyzed and combined to remove distortions and background signals from cSLO movies. The advantages of the temporal correction include a better fit of the image intensity function to the model and the avoidance of local averaging that would impair the spatial resolution. The enhancement techniques are used both as preprocessing and as a part of the fitting technique, which makes its performance noise-resistant.

7962-168, Poster Session

Reconstruction of high-resolution fluorescence microscopy images based on axial tomography

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For a reliable understanding of cellular processes, high resolution 3D images of the investigated cells are necessary. Unfortunately, the ability of fluorescence microscopes to image a cell in 3D is limited since the resolution along the optical axis is by a factor of two to three worse than the transversal resolution. Standard microscopy image deblurring algorithms like the Total Variation regularized Richardson Lucy algorithm are able to improve the resolution but the problem of a lower resolution in direction along the optical axis remains. However, it is possible to overcome this problem using Axial Tomography providing tilted views of the object by rotating it under the microscope. The rotated images contain additional information about the objects and an advanced method to reconstruct a 3D image with an isotropic resolution is presented here. First, bleaching has to be corrected in order to allow a valid registration correcting translational and rotational shifts. Hereby, a multi-resolution rigid registration method is used in our method. A single high-resolution image can be reconstructed on basis of all aligned images using an extended Richardson Lucy method. In addition, a Total Variation regularization is applied in order to guarantee a stable reconstruction result. The results for both simulated and real data show a considerable improvement of the resolution in direction of the optical axis.

7962-169, Poster Session

Improved 3D wavelet-based de-noising of fMRI data

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Functional MRI (fMRI) data analysis deals with the problem of detecting very weak signals in very noisy data. Smoothing with a Gaussian kernel is often used to decrease noise at the cost of losing spatial specificity. We present a novel wavelet-based 3-D technique to remove noise in fMRI data while preserving the spatial features in the maps. Each volume is decomposed into eight volumetric sub-bands using a separable 3-D stationary wavelet transform. Each of the detail sub-bands are then treated through the main denoising module. This module first determines whether a voxel in a particular sub-band is signal or noise using a variance threshold. The aforementioned binary mask is further utilized to compute shrinkage factors through a hierarchical framework which utilizes information from a sub-band at next higher level to estimate denoised coefficients at the current level until the lowest level is estimated. These de-noised sub-bands are then reconstructed back to the spatial domain using an inverse wavelet transform. The denoised fMRI data set may then be used for any type of statistical testing, for example, general linear model (GLM) or signal separation using independent component analysis (ICA). The proposed method enables the preservation of shape of the actual activation regions associated with the BOLD activity in addition to achieving high specificity as compared to other methods. We present and compare the results of our proposed method against the bilateral filter and FWHM (Full Width, Half Maximum) Gaussian kernels (multiple sizes) which are widely used in smoothing fMRI data. The qualitative comparison using sensitivity and specificity statistics of the activation maps obtained through methods such as GLM and ICA. The test data set is comprised of fMRI scans acquired from 20 healthy subjects while they performed a simple block design motor-tapping task. The data is pre-processed (slice time correction, spatial normalization, motion correction) using the SPM package, with the exception of smoothing for obvious reasons.

7962-171, Poster Session

Single image super-resolution using the FREBAS transform

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Super-resolution is a method of restoring an image by extrapolating the signal beyond the band-limited receiver system. In the present study, image magnification with super-resolution effects using the FREBAS transform is investigated. FREBAS transform which is a kind of multi-resolution image analysis and is considered as convoluted images with phase modulated quadratic phase functions. Since FREBAS decomposed images have rather strong correlations with neighboring decomposed images each other, signal interpolation of extrapolation is feasible using some a priori information, i.e. the input image is the real-valued object In proposed method, firstly FREBAS decomposed image is zero-filled to be twice the size of input NxM image and then iterative calculations based on the Gerchberg algorithm is executed using the constraint that the input image is the real-valued object in the image space and the replacement of the central NxM signal in the extended 2Nx2M FREBAS signal space with the original firstly-calculated FREBAS decomposed signal. Since FREBAS transform allows optional scaling of images, we have investigated the relation between a scaling parameter D and the improvement in resolution. It was shown that the spatial resolution in the central domain is improved when D is an even number, whereas the peripheral domain is improved when D is an odd number. In addition the frequency spectrum is extrapolated to certain extent beyond the Nyquist criteria in the Fourier space of input image.

7962-172, Poster Session

Phase-unwrapping of differential phase-contrast data using attenuation information

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Phase-contrast imaging approaches suffer from a severe problem which is known in Magnetic Resonance Imaging (MRI) and Synthetic Aperture Radar (SAR) as phase-wrapping. This work focuses on an unwrapping solution for the grating based phase-contrast interferometer with X-rays. The approach delivers three types of information about the x-rayed object - the absorption, differential phase-contrast and dark-field information whereas the observed differential phase values are physically limited to the interval (-pi, pi]; values higher or lower than the interval borders are mapped (wrapped) back into it.

In contrast to existing phase-unwrapping algorithms for MRI and SAR the presented algorithm uses the absorption image as additional information to identify and correct phase-wrapped values. The idea of the unwrapping algorithm is based on the observation that at locations with phase-wrapped values the contrast in the absorption image is high and the behavior of the gradient is similar to the real (unwrapped) phase values. This can be expressed as a cost function which has to be minimized by an integer optimizer. Applied on simulated and real datasets showed that 95.6 % of phase-wraps were correctly unwrapped and the rest stayed unmodified.

Based on the results we conclude that it is possible to use the absorption information in order to identify and correct phase-wrapped values.

7962-173, Poster Session

Iterative wavelet thresholding for rapid MRI reconstruction

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An iterative thresholding algorithm for reconstruction of images from limited Fourier observations is proposed. The proposed method takes advantage of the sparsity in the wavelet domain. Initializing with a minimum-energy reconstruction, the object of interest is reconstructed by going through a sequence of thresholding and recovery iterations. The performance of the proposed algorithm is experimentally evaluated and compared to other state-of-the-art methods. In particular, we show that the quality of reconstruction is increased compared to Total variation regularization, l1 regularization, and the conventional Papoulis-Gerchberg algorithm.

7962-174, Poster Session

Quantitative and qualitative image quality analysis of super resolution images from a low cost SLO

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The lurking epidemic of eye diseases caused by diabetes and aging will put more than 130 million Americans at risk of blindness by 2020. Screening has been touted as a means to prevent blindness by identifying those individuals at risk. However, the cost of most of today's commercial retinal imaging devices makes their use economically impractical for mass screening. Thus, low cost devices are needed. However, low cost often comes at the expense of image quality with high levels of noise and distortion hindering the clinical evaluation of those retinas.

A software-based super resolution (SR) reconstruction methodology that produces images with improved resolution and quality from multiple low resolution (LR) observations is introduced. The LR images are taken with a low-cost Scanning Laser Ophthalmoscope (SLO). The non-redundant information of these LR images is combined to produce a single image in an implementation that also removes noise and imaging distortions while preserving fine blood vessels and small lesions.

The feasibility of using the resulting SR images for screening of eye diseases was tested using quantitative and qualitative assessments. Qualitatively, expert image readers evaluated their ability of detecting clinically significant features on the SR images. Quantitatively, measures of image quality were calculated from SR images and compared to subject-matched images from the commercial fundus imagers. Preliminary results show that the SR images have indeed enough quality and spatial detail for screening purposes.

7962-176, Poster Session

A maximum likelihood estimation method for denoising magnitude MRI using restricted local neighborhood

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In this paper, we propose a method to denoise magnitude MRI based on the Maximum Likelihood (ML) estimation method using a restricted local neighborhood. From a statistical point of view, ML estimation method is known to give optimal results and can be successfully applied for estimating the true signal from an MR image by incorporating the

noise hypothesis provided that the underlying area is constant. The direct ML approach to estimate the true underlying intensity from an MR image is to apply the ML estimation method locally by constructing a window around each pixel in the image with the assumption that if the window is small enough, the underlying amplitude can be considered as constant. However, the assumption that the signal in the selected neighborhood area is constant is not always valid in an image and, as a result, the edges in the image get blurred and the fine structures will be destroyed. As a solution to this problem, we put forward the concept of using a restricted local neighborhood where the true intensity for each noisy pixel is estimated from a set of selected neighboring pixels. To this end, a reference image is created from the noisy image using a recently proposed non local means algorithm. This reference image is used as a prior for further noise reduction. A scheme is developed to locally select an appropriate subset of pixels from which the underlying signal is estimated. Experimental results based on PSNR, SSIM and Bhattacharrya coefficient from synthetic and real MRI demonstrate the superior performance of the proposed method over other state of the art methods.

7962-177, Poster Session

SinoCor: a clinical tool for sinogram-level patient motion correction in SPECT

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We present a simple method for correcting patient motion in SPECT. The targeted motion type is a momentary shift in patient's body position caused by coughing, sneezing or a need to shift weight. When detected by the radiology technologist, such motion sometimes causes the scan data to be discarded and the scan to be repeated, thus imposing extra costs and unnecessary health risks to the patients. We propose a partial solution to this problem in the form of a graphical interactive software tool SinoCor that allows instant correction for the simplest types of motion. SinoCor is integrated with the sinogram viewer and used for the initial check of the scan data. It allows the technologists to interactively detect the instances of motion and determine the motion parameters by achieving consistent picture of the sinogram. Two types of motion are corrected by using the algorithms: translational motion of the patient and small angle rotation about in-plane axes. All of the corrections are performed at the sinogram level, after which the images are reconstructed using hospital's/organization's standard reconstruction software. SinoCor is platform-independent, it requires no modification of the acquisition protocol and other processing software, and needs minimal personnel training. Our approach has been validated using both a phantom and a patient SPECT scans. In the presentation, we plan to describe the principal architecture of SinoCor software and illustrate its performance on a series of patient datasets.

7962-178, Poster Session

Noise-resistant adaptive scale using stabilized diffusion

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Semi-locally adaptive models have appeared in medical imaging literature in the past years. In particular, generalized scale models (or g-scale for short) have been introduced to effectively overcome the shape, size, or anisotropic constraints imposed by previous local morphometric scale models. The g-scale models have shown interesting theoretical properties and an ability to drive improved image processing as shown in previous works. In this paper, we present a noise-resistant variant for g-scale set formation, which we refer to as stabilized scale (s-scale) because of its stabilized diffusive properties. This is a modified diffusion process wherein a well-conditioned and stable behavior in the vicinity of boundaries is defined. Yet, s-scale includes an intensity-merging dynamics behavior in the same manner as that found in the switching control of a nonlinear system. Basically we introduce, in the evolution of the diffusive model, a behavior state to drive neighboring voxel intensities to larger and larger iso-intensity regions. In other words, we drive our diffusion process to a coarser and coarser piecewise-constant approximation of the original scene. This strategy reveals a well-known behavior in control theory, called sliding modes. Evaluations on a mathematical phantom, the Brainweb, MR and CT data sets were conducted. The s-scale has shown better performance than the original g-scale under moderate to high noise levels.

7962-179, Poster Session

Mapping spatio-temporal filtering algorithms used in fluoroscopy to single core and multicore architectures

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Low dose X-ray image sequences, as obtained in fluoroscopy, often exhibit high levels of noise that must be suppressed in real-time, while preserving diagnostic structures. Multi-step adaptive filtering approaches, often involving spatio-temporal filters, are typically used to achieve this goal. In this work typical fluoroscopic image sequences, heavily corrupted with Poisson noise, are processed using various filtering schemes. The noise suppression of the schemes is evaluated using objective image quality measures. Two adaptive spatio-temporal schemes, the first one using object detection and the second one using unsharp masking, are chosen as representative approaches for different fluoroscopy procedures and mapped on to Texas Instruments (TI) high performance digital signal processors (DSP). The paper explains the fixed point design of these algorithms and evaluates its impact on overall system performance. The fixed point versions of these algorithms, appropriate for these fixed point processors, are mapped onto the TI's C64x+ core using instruction-level parallelism to effectively use its VLIW architecture. The overall data flow has been carefully planned to reduce cache and data movement overhead, while working with large medical data sets. Apart from mapping these algorithms on to TI's single core DSP architecture, the work is looking at parallelizing the operations to leverage existing and next generation multi-core DSP architectures. Again the data arrangement and flow is being optimized to minimize inter-processor messaging and data movement overhead.

7962-180, Poster Session

Simple and efficient lossless and near-lossless transformation method for grayscale medical images

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Medical images include human body pictures and are used in diagnosis purpose and surgical plan. Compression of medical images, is an application of medical imaging which is widely used in different applications such as profiling patients data and transmission systems. According to importance of information in medical images, lossless or near-lossless compression is preferred for medical images. In real time application, such as Telemedicine and online diagnosis systems, hardware implementation accelerates the whole process. Therefore, a simple compression algorithm works more efficient. Transformation is one of the major parts of a compression algorithm and used to decorrelate the input image. Lossless JPEG, JPEG-LS and JPEG2000 are few famous lossless compression methods. Lossless JPEG and LPEG-LS used prediction model for image transformation. On the other hand, JPEG2000 used Discrete Wavelet Transform (DWT) for this goal. DWT works better than prediction model such as Differential Pulse Code Modulation (DPCM), however, it is more complex. In this paper, we introduced a new method of lossless or near-lossless transformation

for grayscale medical images which is based on prediction model by improving predicting ability. Further, we tried to simplify the new method by introducing a low complex algorithm to be sufficient for real time applications and as a result hardware implementation. The new method has better attribute compare to previous methods such as DWT of JPEG2000 and DPCM due to its redundancy reduction and low complexity. Finally, we applied the new method on few CT and MRI medical images and compare the results with previous methods. Simulations proved the ability of the new method either.

7962-17, Session 4

Integrated segmentation of cellular structures

P. O. Ajemba, Y. Al-Kofahi, R. Scott, M. J. Donovan, G. Fernandez, Aureon Biosciences, Inc. (United States)

Automatic segmentation of cellular structures is an essential step in image Cytometry and Histology. Despite substantial progress, better automation and improvements in accuracy and adaptability to novel applications are needed. In applications utilizing multi-channel immuno-fluorescence images, challenges include misclassification of epithelial and stroma nuclei, irregular nuclei and cytoplasm boundaries, and over and under-segmentation of clustered nuclei. Variations in image acquisition conditions and artifacts from nuclei and cytoplasm images often confound existing algorithms in practice. In this paper, we present a robust and accurate algorithm for jointly segmenting cell nuclei and cytoplasm using a combination of ideas to reduce the aforementioned problems. First, an adaptive process that includes top-hat filtering, Eigenvalues-of-Hessian blob detection and distance transforms is used to estimate the inverse illumination field and correct for intensity non-uniformity in the nuclei channel. Next, a minimum-error-thresholding based binarization process and seed-detection combining Laplacian-of-Gaussian filtering constrained by a distance-map-based scale selection is used to identify candidate seeds for nuclei segmentation. The initial segmentation using a local maximum clustering algorithm is refined using minimum-error-thresholding technique. Final refinements include an artifact removal process specifically targeted at lumens and other problematic structures and a systemic decision process to reclassify nuclei objects near the cytoplasm boundary as epithelial or stroma. Segmentation results were evaluated using 48 realistic phantom images with known ground-truth. The overall segmentation accuracy exceeds 94%. The artifact removal process worked in 90% of cases. Having been tested on over 6000 images, the algorithm has been deployed in a high-volume histology analysis application.

7962-18, Session 4

Identification and classification of cells in multispectral microscopy images of lymph nodes

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Accurate detection and classification of stained cells in microscopy images enable quantitative measurements of cell distributions and spatial structures, and are crucial for developing new analysis tools for medical studies and applications such as cancer diagnosis and treatment. In this paper, we present a learning based approach for identifying different types of cells in tumor-draining lymph nodes (TDLNs) and locating their centroid positions. With our approach, a set of features based on the eigenvalues of the Hessian matrix is constructed for each pixel to determine whether the local shape is elliptic. The elliptic features are then used together with the intensity-based ring scores as the feature set for the supervised learning based method. By using this new feature set, a classifier based on random forest is trained from a set of training samples of different cell types. In order to overcome the difficulties of classifying cells with varying stain qualities, size, and shapes, we built a large set of prior training data from a variety of tissue sections. To deal with the issue of multiple overlapping cell nuclei, we propose to utilize the spikes of the outer medial axis to detect and detach the touching cells. As a result, the centroid position of each identified cell is pinpointed. The experimental data show that our proposed method achieves higher recognition rates than previous methods, reducing significantly the human interaction effort.

7962-19, Session 4

Development of a stained cell nuclei counting system

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This paper presents a novel cell counting system which exploits the Fast Radial Symmetry Transformation (FRST) algorithm. The driving force behind our system is a research on neurogenesis in intact nervous system of Manduca Sexta or Tobacco Hornworm. The brain cells undergoing cell division in this species are counted to study the impact of age, food, environment etc, on neurogenesis. The varying thickness of the intact nervous system often yields the images with inhomogeneous background and inconsistencies like varying illumination, variable contrast, irregular cell size etc. For automated counting, such inhomogenity and inconsistencies must be addressed, which no existing work has done successfully. Thus, our goal is to devise a new cell counting algorithm for the images with non-uniform background. Our solution adapts FRST: a computer vision algorithm which is designed to detect points of interest on circular regions such as eyes. This algorithm enhances the occurrences of the stained-cell nuclei in 2D digital images and negates the problems caused by its inhomogenity. Besides FRST, our algorithm employs standard image processing methods, such as mathematical morphology and connected component analysis. We have evaluated the developed cell counting system with fourteen digital images of Tobacco Hornworm's nervous system collected for this study with ground-truth cell counts by biology experts. Experimental results show that our system has a minimum error of 1.41% and mean error of 16.68% which is at least forty-four percent better than the algorithm without FRST.

7962-20, Session 4

Texture analysis of clinical radiographs using radon transform on a local scale for differentiation between post-menopausal women with and without hip fracture

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With the ageing of populations in the industrialized world the number of age-related bone fractures is steadily on the rise. It is of great economic interest to provide easily accessible, low-cost screening tests for the assessment of an individual´s fracture-risk in order to initiate preventive action.

Currently, bone-mineral-density (BMD) obtained from DXA (dual-energy x-ray-absorptiometry) is the standard clinical method for the assessment of an individual´s bone strength. Availability of DXA is typically restricted to specialized medical centers. X-ray imaging, on the other hand, is a cheap, universally available modality. Radiographs of the peripheral skeleton, such as the ankle, range among the most frequently ordered diagnostic procedures for exclusion or confirmation of fracture.

In our study we test the hypothesis that parameters extracted from the Radon Transform (RT) of trabecular bone texture depicted by a lateral x-ray projection of the heel bone allow to differentiate between patients with fractures of the ankle and healthy controls.

Our analysis is conducted on 100 post-menopausal women. Preliminary

results indicate that texture properties extracted by RT in x-ray-films of the heel bone are closely correlated with the fracture status. The evaluation method may serve as a substitute indicator for the mechanical integrity of an individual´s skeleton.

7962-21, Session 4

Detection of rheumatoid arthritis using infrared thermal imaging

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Rheumatoid arthritis (RA) is an inflammatory disease that causes pain, swelling, stiffness, and loss of function in the joints and is difficult to diagnose in its early stages. However, an early diagnosis can delay the onset of severe disability for many years. Infrared thermography offers a potential approach to detect changes in degree of inflammation. To test this hypothesis, thermal images were collected from joints of hands, wrists, palms, and knees of 18 normal subjects (control group) and from 13 patients diagnosed with Rheumatoid Arthritis (RA). Regions of interest (ROIs) were manually selected from all subjects and all parts imaged. For each subject, values were calculated from the temperature measurements: Mode/Max, Median/Max, Min/Max, Variance, Max-Min, (Mode-Mean)2, and Mean/Min. The data sets did not have a normal distribution, therefore non parametric tests (Kruskal-Wallis and Ranksum) were applied to assess if the data from the control group and the patient group were significantly different. Results indicate that: (i) RA can be detected on patients with the disease; (ii) the best joints to image are the metacarpal phalangeal of the 2nd and 3rd fingers and the knees; the difference between the two groups was significant at the 0.05 level; (iii) the best calculations to differentiate between normal subjects and patients with RA are the Mode/Max, Variance, and Max-Min. The conclusion is that it is possible to reliably detect RA in patients using infrared thermal imaging. Future work will analyze the other joints imaged and the analysis process will be automated.

7962-22, Session 5

Identifying intrasulcal medial surfaces for anatomically consistent reconstruction of the cerebral cortex

S. Osechinskiy, F. Kruggel, Univ. of California, Irvine (United States)

A novel approach to identifying poorly resolved boundaries between adjacent sulcal cortical banks in MR images of the human brain is presented. The algorithm calculates an electrostatic potential field in a partial differential equation (PDE) model of an inhomogeneous “dielectric” layer of gray matter that surrounds “conductive” white matter. Correspondence trajectories and geodesic distances are computed along the streamlines of the potential field gradient using PDEs in a Eulerian framework. The skeleton of a sulcal medial boundary is identified by a simple procedure that finds irregularities/collisions in the field of correspondences. The skeleton detection procedure is robust to noise, does not produce spurious artifacts and does not require tunable parameters. Results of the algorithm are compared with a closely related technique, called Anatomically Consistent Enhancement (ACE) (Han et al. “CRUISE: Cortical reconstruction using implicit surface evolution”, 2004). Results demonstrate that the approach proposed here has a number of advantages over ACE and produces skeletons with a more regular structure. This algorithm was developed as a part of a more general PDE-based framework for cortical reconstruction, which integrates the potential field gradient flow and the skeleton barriers into a level set deformable model. This technique is primarily aimed at anatomically consistent and accurate reconstruction of cortical surface models in the presence of imaging noise and partial volume effects, but the identified intrasulcal medial surfaces can serve other purposes as well, e.g. as landmarks in nonrigid registration, or as sulcal ribbons that characterize the cortical folding.

7962-23, Session 5

Detection and mapping of delays in early cortical folding derived from in utero MRI

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Understanding human brain development in utero and detecting cortical abnormalities related to specific clinical conditions is an important area of research. In this paper, we describe and evaluate methodology for detection and mapping of delays in early cortical folding from population-based studies of fetal brain anatomies imaged in utero. We use a general linear modeling framework to describe spatiotemporal changes in curvature of the developing brain and explore the ability to detect and localize delays in cortical folding in the presence of uncertainty in estimation of the fetal age. We apply permutation testing to examine which regions of the brain surface provide the most statistical power to detect a given folding delay at a given developmental stage. The presented methodology is evaluated using MR scans of fetuses with normal brain development and gestational ages ranging from 20.57 to 27.86 weeks. This period is critical in early cortical folding and the formation of the primary and secondary sulci. Finally, we demonstrate a clinical application of the framework for detection and localization of folding delays in fetuses with isolated mild ventriculomegaly.

7962-24, Session 5

Topologically correct cortical segmentation using Khalimsky’s cubic complex framework

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Automatic segmentation of the cerebral cortex from magnetic resonance brain images is a valuable tool for neuroscience research. Due to the presence of noise, intensity non-uniformity, partial volume effects and the highly convoluted shape of the cerebral cortex, segmenting the brain in a robust, accurate and topologically correct way still poses a challenge.

In this paper we describe a topologically correct Expectation Maximisation based Maximum a Posteriori segmentation algorithm formulated within the Khalimsky cubic complex framework, where both the solution of the EM algorithm and the information derived from a geodesic distance function are used to locally modify the weighting of a Markov Random Field and drive the topology correction operations.

Experiments performed on 20 Brainweb datasets show that the proposed method obtains a topologically correct segmentation without significant loss in accuracy when compared to two well established techniques.

7962-25, Session 5

A novel Riemannian metric for analyzing HARDI data

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We propose a novel Riemannian framework for analyzing orientation distribution functions (ODFs) in HARDI data sets, for use in comparing, interpolating, averaging, and denoising ODFs. A recently used Fisher-Rao

metric does not provide physically feasible solutions, and we suggest a modification that removes orientations from ODFs and treats them as separate variables. This way a comparison of any two ODFs is based on separate comparisons of their shapes and orientations. Furthermore, this provides an explicit orientation at each voxel for use in tractography. We demonstrate these ideas by computing geodesics between ODFs and Karcher means of ODFs, for both the original Fisher-Rao and the proposed framework.

7962-26, Session 5

Resolving complex fibre configurations using two-tensor random-walk stochastic algorithms

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Fibre tractography using diffusion tensor imaging allows the study of anatomical connectivity of the brain, and is an important diagnostic tool for a range of neurological diseases. Deterministic tractography algorithms assume that the fibre direction coincides with the principal eigenvector of a single diffusion tensor. This is, however, not the case for regions with crossing fibres. In addition noise introduces uncertainty and makes the computation of fibre directions difficult. Stochastic tractography algorithms have been developed to overcome the uncertainties of deterministic algorithms. However, generally, both parametric and non-parametric stochastic algorithms require longer computational time and large amounts of memory. Multi-tensor fibre tracking methods can alleviate these problems when crossing fibres are encountered. In this study simple and computationally efficient random-walk algorithms are described for estimating anatomical connectivity in white matter. These algorithms are then applied to a two-tensor model to compute the probabilities of connections between regions with complex fibre configurations. We analyze the random-walk models quantitatively using simulated data and estimate the optimal parameter values of the models. The performance of the tracking algorithms is verified using a physical phantom and an in vivo dataset with a wide variety of seed points. The results confirm the effectiveness of the proposed approach, which gives comparable results to other stochastic methods. Our approach is however significantly difference faster and requires less memory. The results of two-tensor random-walk algorithms demonstrate that our algorithms can accurately identify fibre bundles in complex fibre regions.

7962-27, Session 5

Efficient, graph-based white matter connectivity from orientation distribution functions via multi-directional graph propagation

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The use of regional connectivity measurements derived from diffusion imaging datasets has become of considerable interest to the neuroimaging community in order to better understand cortical and subcortical white matter connectivity. Current connectivity assessment methods are based on streamline fiber tractography, usually applied in a Monte-Carlo fashion. In this work we present a novel, graph-based method that performs a fully deterministic, efficient and stable connectivity computation. The method handles crossing fibers and deals well with multiple seed regions. The computation is based on a multi-directional graph propagation method applied to sampled orientation distribution function (ODF), which can be computed directly from the original diffusion imaging data. We show early results of our method on synthetic and real datasets. The results illustrate the potential of our method towards subject-specific connectivity measurements that are performed in an efficient, stable and reproducible manner. Such individual connectivity measurement would be well suited for application in population studies of neuropathology, such as Autism, Huntington's Disease, Multiple Sclerosis or leukodystrophies. The proposed method is generic and could be easily applied to non-diffusion, multi-directional data, for example for vascular tracking from local directional filter data in MR Angiography.

7962-28, Session 6

Landmark-driven parameter optimization for non-linear image registration

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Registration is one of the most common research areas in medical image processing. It is required for example for image fusion, motion estimation, patient positioning or generation of medical atlases.

In most registration approaches, parameters have do be determined, most commonly a parameter indicating to what extend the transformation is required to be smooth. Its optimal choice depends on multiple factors like the actual application and the occurrence of noise in the images, and may therefore vary from case to case. Moreover, multi-scale approaches are commonly applied on registration problems and demand for further adjustment of the parameters.

In this paper, we present a landmark-based approach for automatic parameter optimization in image registration. In a first step, corresponding landmarks are automatically detected in the images to match. Registration is then executed for a set of parameter values and its optimum is determined examining the mean landmark distance after registration.

The approach is evaluated for the registration of the lungs based on 12 thoracic CT data sets. Experiments show that the mean target registration error (TRE) can be reduced on average by 0.12 mm using automatic parameter optimization.

7962-29, Session 6

Temporal subtraction of chest radiographs compensating pose differences

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Temporal subtraction techniques using 2D image registration improve the detectability of interval changes from chest radiographs. Although such methods are well known for some time they are not widely used in radiologic practice. The reason are strong pose differences between these follow-up acquisitions with a time interval of months to years in between. Such strong perspective differences occur in a reasonable number of cases. They cannot be compensated by available image registration methods and thus mask interval changes to be undetectable. A method is proposed to estimate a 3D pose difference by the adaptation of a 3D rib cage model to both projections. The difference between both is then compensated for, thus producing a subtraction image with virtually no change in pose. No 3D image data is used. The accuracy of pose estimation is validated with chest phantom images under controlled geometric conditions.

7962-30, Session 6

An accurate 3D shape context based non-rigid registration method for mouse whole-body skeleton registration

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Small animal image registration is challenging because of its joint structure and posture and position difference in each acquisition without a standard micro-CT/PET scan protocol. In this paper, we face the issue of mouse whole-body skeleton registration from CT images. A mesh analysis method is applied to distinguish the major skeleton (an integral connectivity of skull, spine, pubis, ischium and two hind limbs), sternum and two fore limbs according to the structural features of mouse skeletons extracted from CT images. A novel method is developed for analyzing mouse hind-limb and fore-limb postures based on geodesic path algorithm and then registering the major skeleton and fore limb skeletons initially by thin-plate spline (TPS) transform based on the obtained geodesic paths and correspondence fields. A target landmark correction method is proposed for improving the registration accuracy of the improved 3D shape context non-rigid registration method we previously proposed. A novel non-rigid registration framework, combining the skeleton posture analysis, geodesic path based initial alignment and 3D shape context model non-rigid registration, is proposed for mouse whole-body skeleton registration. The performance of the proposed methods and framework was tested on 12 pairs of mouse whole body skeletons. The experimental results demonstrated the flexibility, stability and accuracy of the proposed framework for automatic mouse whole body skeleton registration.

7962-31, Session 6

Iterative closest point algorithm with anisotropic weighting and its application to fine surface registration

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The Iterative Closest Point (ICP) algorithm is a widely used method for geometric alignment of 3D models. Given two roughly aligned shapes represented by two point sets, the algorithm iteratively establishes point correspondences given the current alignment of the data and computes a rigid transformation accordingly. It can be shown that the method converges to an at least local minimimum with respect to a mean-square distance metric. From a statistical point of view, the algorithm implicitly assumes that the points are observed with isotropic Gaussian noise. In this paper, we (1) present the first variant of the ICP that accounts for anisotropic localization uncertainty in both shapes as well as in both steps of the algorithm and (2) show how to apply the method for robust fine registration of surface meshes. According to an evaluation on medical imaging data, the proposed method is better suited for fine surface registration than the original ICP, reducing the target registration error (TRE) for a set of targets located inside or near the mesh by more than 50% on average.

7962-32, Session 6

Incorporating hard constraints into non-rigid registration via nonlinear programming

D. V. N. Luong, D. Rueckert, B. Rustem, Imperial College London (United Kingdom)

Non-rigid image registration is a key technique in medical image analysis. In conventional non-rigid registration the whole image is deformed in a non-rigid fashion. However, in some clinical applications, the registration process is required to maintain rigidity in some parts of the image (e.g. bones) while other parts of the image (e.g. soft tissues) can deform in a non-rigid fashion. In this paper, we employ a nonlinear programming approach to solve the registration problem efficiently while ensuring the feasibility of the solution with respect to rigidity constraints.

Our approach differs from others from an optimization perspective. Unlike the frequently used regularization formulation that incorporates soft constraints into energy function, we impose the local rigidity requirements as hard constraints. The constrained optimization problem is solved by nonlinear programming. The nonlinear programming formulation allows us to exploit the constraints in order to reduce the dimensionality of the optimization problem. In addition, we use dense registration framework to control the deformation at every voxel explicitly. Therefore, unconstrained voxels are not affected by the method. Experimental results from synthetic and MR images of the knee show that our method converges to the optimal solution faster and satisfies the rigidity constraints of the transformation during registration process. The result is a more realistic estimation of rigid and non-rigid deformations.

7962-33, Session 7

Mapping the distance between brain and endocast and their asymmetries

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The primary goal of this paper is to describe i) the pattern of pointwise distances between the human brain (pial surface) and the inner surface of the skull (endocast) and ii) the pattern of pointwise bilateral asymmetries of these two structures. We use a database of MR images to segment meshes representing the outer surface of the brain and the endocast. We propose automated computational techniques to assess the endocast-to-brain distances and endocast-and-brain asymmetries, based on a simplified yet accurate representation of the brain surface, that we call the brain hull. We compute two meshes representing the mean endocast and the mean brain hull to assess the two patterns in a population of normal controls. The results show i) a pattern of endocast-to-brain distances which are symmetrically distributed with respect to the mid-sagittal plane and ii) a pattern of global endocast and brain hull asymmetries which are consistent with the well-known Yakovlevian torque. Our study is a first step to validate the endocranial surface as a surrogate for the brain in fossil studies, where a key question is to elucidate the evolutionary origins of the brain torque. It also offers some insights into the normal configuration of the brain/skull interface, which could be useful in medical imaging studies (e.g. understanding atrophy in neurodegenerative diseases or modeling the brain shift in neurosurgery).

7962-34, Session 7

Mandible shape modeling using the second eigenfunction of the Laplace-Beltrami operator

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The second Laplace-Beltrami eigenfunction provides an intrinsic geometric way of establishing natural coordinates for elongated 3D anatomical structures obtained from imaging images. This approach is used to establish the centerline of the segmented human mandible and provides automated anatomical landmarks across subjects. These landmarks are then used to quantify the growth pattern of the mandible between ages 0 and 20.

7962-35, Session 7

Manifold learning for image-based breathing gating in MRI

M. Yigitsoy, C. Wachinger, N. Navab, Technische Univ. München (Germany)

Respiratory motion is a challenging factor for image-guided procedures in the abdominal region. Target localization, an important issue in applications like radiation therapy, becomes difficult due to this motion. Therefore, it is necessary to detect the respiratory signal to have a higher accuracy in planning and treatment. We propose a novel image-based breathing gating method to recover the breathing signal directly from the image data. For the gating we use Laplacian eigenmaps, a manifold learning technique, to determine the low-dimensional manifold embedded in the high-dimensional space. Since Laplacian eigenmaps assign each 2D MR slice a coordinate in a low-dimensional space by respecting the neighborhood relationship, they are well suited for analyzing the respiratory motion. We perform the manifold learning on MR slices acquired from a fixed location. Then, we use the resulting respiratory signal to derive a similarity criterion to be used in applications like 4D MRI reconstruction. We perform experiments on liver data using one and three dimensions as the dimension of the manifold and compare the results. The results from the first case show that using only one dimension as the dimension of the manifold is not enough to represent the complex motion of the liver caused by respiration. We successfully recover the changes due to respiratory motion by using three dimensions. The proposed method has the potential of reducing the processing time for the 4D reconstruction significantly by defining a search window. It is fully automatic and does not require any prior information or training data.

7962-36, Session 7

Active shape models unleashed

M. Kirschner, S. Wesarg, Technische Univ. Darmstadt (Germany)

Active Shape Models (ASMs) are a popular family of segmentation algorithms which combine local appearance models for boundary detection with a Statistical Shape Model (SSM). They are especially popular in medical imaging due to their ability for fast and accurate segmentation of anatomical structures even in large and noisy 3D images. A well-known limitation of ASMs is that the shape constraints are over restrictive, because the segmentations are bounded by the Principal Component Analysis (PCA) subspace learned from the training data. To overcome this limitation, we propose a new energy minimization approach which combines an external image energy with an internal shape model energy. Our shape energy uses the Distance From Feature Space (DFFS) concept to allow deviations from the PCA subspace in a theoretically sound and computationally fast way. In contrast to previous approaches, our model does not rely on post-processing with constrained free-form deformation or additional complex local energy models. In addition to the energy minimization approach, we propose a new method for liver detection, a new method for initializing a SSM and an improved k-Nearest Neighbour (kNN)-classifier for boundary detection. Our ASM is evaluated with leave-one-out tests on a data set with 34 tomographic CT scans of the liver and is compared to an ASM with standard shape constraints. The quantitative results of our experiments show that we achieve higher segmentation accuracy than the standard approach.

7962-37, Session 7

Automatic shape based deformable registration of multiphase contrast enhanced liver CT volumes

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The detection and assessment of hepatic diseases is based on examination of multiphase liver CT volumes. Since phases contain complementary information, registration enables the radiologist to fuse the needed information for diagnosis. This work presents a novel multi-stage approach for automatic registration of the liver in contrast enhanced CT volumes. Unlike other methods, our approach is based on automatic pre-segmentation of the liver in the different phases. Using the resulting shape information the volumes are coarsely registered using a landmark-based registration. Subsequently, deformations caused by the patient's breathing are compensated by an elastic Demons algorithm with a boundary distance based speed function. This allows for a high accuracy natural deformation without having to rely on error-prone extraction and matching of the liver's internal structure in complementary phases. Furthermore, since shape information is given, surrounding structures can be omitted which significantly speeds up registration. We evaluated our method using 22 CT volumes from 11 patients. The matching quality of outer shape and internal structures was validated by radiology experts. The high quality results of our approach suggest its applicability in clinical practice.

7962-38, Session 7

Real-time cardiac surface tracking from sparse samples using subspace clustering and maximum-likelihood linear regressors

V. Singh, A. H. Tewfik, Univ. of Texas, Austin (United States)

Cardiac minimal invasive surgeries such as catheter based radio frequency ablation of atrial fibrillation requires high-precision tracking of inner cardiac surfaces in order to ascertain constant electrode-surface contact. Majority of cardiac motion tracking systems are either limited to outer surface or track limited slices/sectors of inner surface in echocardiography data which are unrealizable in MIS due to the varying resolution of ultrasound with depth and speckle effect. In this paper, a system for high accuracy real-time 3D tracking of both cardiac surfaces using sparse samples of outer-surface only is presented. This paper presents a novel approach to model cardiac inner surface deformations as simple functions of outer surface deformations in the spherical harmonic domain using multiple maximal-likelihood linear regressors. Tracking system uses subspace clustering to identify potential deformation spaces for outer surfaces and trains ML linear regressors using pre-operative MRI/CT scan based training set. During tracking, sparse-samples from outer surfaces are used to identify the active outer surface deformation space and reconstruct outer surfaces in real-time under least squares formulation. Inner surface is reconstructed using tracked outer surface with trained ML linear regressors. High-precision tracking and robustness of the proposed system are demonstrated through results obtained on a real patient dataset with tracking root mean square error <=(0:23+/-0:04)mm and <=(0:30+/-0:07)mm for outer & inner surfaces respectively.

7962-39, Session 8

A novel adaptive scoring system for segmentation validation with multiple reference masks

J. H. Moltz, J. Rühaak, H. K. Hahn, H. Peitgen, Fraunhofer MEVIS (Germany)

The development of segmentation algorithms for different anatomical structures and imaging protocols is an important task in medical image processing. The validation of these methods, however, is often treated as a subordinate task. Since manual delineations, which are widely used as a surrogate for the ground truth, exhibit an inherent uncertainty, it is preferable to use multiple reference segmentations for an objective validation. This requires a consistent framework that should fulfill three criteria: 1) it should treat all reference masks equally a priori and not demand consensus between the experts; 2) it should evaluate the algorithmic performance in relation to the inter-reference variability, i.e., be more tolerant where the experts disagree about the true segmentation; 3) it should produce results that are comparable for different test data.

We show why current state-of-the-art frameworks as the one used at several MICCAI segmentation challenges do not fulfill these criteria and propose a new validation methodology. A score is computed in an adaptive way for each individual segmentation problem, using a combination of volume- and surface-based comparison metrics. These are transformed into the score by relating them to the variability between the reference masks which can be measured by comparing the masks with each other or with an estimated ground truth. We present examples from a study on liver tumor segmentation in CT scans where our score shows a more adequate assessment of the segmentation results than the MICCAI framework.

7962-40, Session 8

Automatic model-based 3D segmentation of the breast in MRI

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A statistical shape model (SSM) is constructed and applied to automatically segment the breast in 3D MRI. We present an approach to automatically construct a SSM: first, a population of 415 semi-automatically segmented breast MRI volumes is groupwise registered to derive an average shape. Second, a surface mesh is extracted and further decimated to reduce the density of the shape representation. Third, landmarks are obtained from the averaged decimated mesh, which are non-rigidly deformed to each individual shape in the training set, using a set of pairwise deformations. Finally, the resulting landmarks are consistently obtained in all cases of the population for further statistical shape model (SSM) generation. A leave-one-out validation demonstrated that near sub-voxel resolution reconstruction (2.5mm) error is attainable when using a minimum of 15 modes of variation. The model is further applied to automatically segment the anatomy of the breast in 3D. We illustrate the results of our segmentation approach in which the model is adjusted to the image boundaries using an iterative segmentation scheme.

7962-41, Session 8

Fully automatic segmentation of complex organ systems: example of trachea, esophagus and heart segmentation in CT images

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Automatic segmentation is a prerequisite to efficiently analyze the large amount of image data produced by modern imaging modalities. Many algorithms exist to segment individual organs or organ systems, e.g., the heart, the trachea, and the esophagus. However, new clinical applications and the progress in imaging technology will require the segmentation of more and more complex organ systems composed of a number of substructures. The goal of this work is to demonstrate that such complex organ systems can be successfully segmented by integrating the individual organs into a general model-based segmentation framework, without tailoring the core adaptation engine to the individual organs. As an example, we address the fully automatic segmentation of the trachea (around its main bifurcation, including the proximal part of the two main bronchi) and the esophagus in addition to the heart with all chambers and attached major vessels. To this end, we integrate the trachea and the esophagus into a model-based cardiac segmentation framework.

Specifically, in a first parametric adaptation step of the segmentation workflow, the trachea and the esophagus share global model transformations with adjacent heart structures. This allows to obtain a robust, approximate segmentation for the trachea even if it is only partly inside the field-of-view, and for the esophagus in spite of limited contrast. The segmentation is then refined in a subsequent deformable adaptation step. We obtained a mean segmentation error of about 0.6mm for the trachea and 2.3mm for the esophagus on a database of 23 volumetric cardiovascular CT images.

Furthermore, we show by quantitative evaluation that our integrated framework outperforms individual esophagus segmentation, and individual trachea segmentation if the trachea is only partly inside the field-of-view.

7962-42, Session 8

Automatic identification of cochlear implant electrode arrays for post-operative assessment

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Cochlear implantation is a procedure performed to treat profound hearing loss. Accurately determining the post-operative position of the implant in vivo would permit studying the correlations between implant position and hearing restoration. To solve this problem, we present an approach based on parametric Gradient Vector Flow snakes to segment the electrode array in post-operative CT. By combining this with existing methods for localizing intra-cochlear anatomy, we have developed a system that permits accurate assessment of the implant position in vivo. The system is validated using a set of seven temporal bone specimens. The algorithms were run on pre- and post-operative CTs of the specimens, and the results were compared to histological images. It was found that assessment of electrode position in histological images is in excellent agreement with assessment using the automatically generated 3D reconstructions.

7962-43, Session 8

Prostate segmentation with local binary patterns guided active appearance models

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Real-time fusion of Magnetic Resonance (MR) and Trans Rectal Ultra Sound (TRUS) images aid in localization of the malignant tissues in TRUS

guided prostate biopsy. Registration performed on segmented contours of the prostate reduces computational complexity and improves the multimodal registration accuracy. However, accurate and computationally efficient segmentation of the prostate in TRUS images could be challenging in the presence of heterogeneous intensity distribution inside the prostate gland, imaging artifacts like speckle noise, shadow regions and low Signal to Noise Ratio (SNR). In our work, we propose to enhance the texture features of the prostate region using Local Binary Pattern (LBP) for the propagation of a shape and appearance based statistical model to segment the prostate in a multi-resolution framework. A parametric model of the propagating contour is derived from Principal Component Analysis (PCA) of prior shape and texture information of the prostate from the training data. The parameters are then modified with the prior knowledge of the optimization space to achieve optimal segmentation. The proposed method achieves a mean Dice Similarity Coefficient (DSC) value of 0.94±0.01 and mean segmentation time of 0.68±0.02 seconds when validated with 50 TRUS images grabbed from a video sequence in a leave-one-out validation framework. Our method performs computationally efficient and accurate prostate segmentation in the presence of intensity heterogeneities and imaging artifacts.

7962-44, Session 9

Probabilistic framework for subject-specific and population analysis of longitudinal changes and disease progression in brain MR images

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Aging and many neurological diseases cause progressive changes in brain morphology. Both subject-specific detection and measurement of these changes, as well as their population-based analysis are of great interest in many clinical studies. Generally, both problems are handled separately. However, as population-based knowledge facilitates subject-specific analysis and vice versa, we propose a unified statistical framework for subject-specific and population-based analysis of brain images. For this, longitudinal MR image sequences of subjects suffering from the same neurological disease are used.

The proposed method simultaneously segments all images in separate tissue classes. This involves the iterative construction of a global probabilistic 3D brain atlas and its alignment to each of the input brain image sequences. Therefore, a maximum a posteriori formulation is used, which is optimized using the expectation maximization algorithm. In order to enable a population-based analysis of the disease progression, an intermediate 4D probabilistic brain atlas is considered, representing a discrete set of disease progression stages. The 4D atlas is simultaneously constructed with the 3D brain atlas by incorporating assignments of each input image (voxelwise) to a particular disease progression stage in the statistical framework. Moreover, these assignments enable both temporal and spatial subject-specific disease progression analyses. This includes detecting delayed or advanced disease progression and indicating the affected regions. The method is validated on a publicly available data set on which it shows promising results.

7962-45, Session 9

A novel local-phase method of automatic atlas construction in fetal ultrasound

S. F. Fathima, S. Rueda, A. Papageorghiou, J. A. Noble, Univ. of Oxford (United Kingdom)

In recent years, fetal diagnostics have relied heavily on clinical assessment and biometric analysis of manually acquired ultrasound images. There is a profound need for automated and standardized evaluation tools to characterize fetal growth and development. This work is aimed at addressing this need through the novel use of population atlas-based evaluators of development and function to characterize fetal growth. The methodology is comprised of an automated database-driven 2D/3D probabilistic atlas construction method, which includes several iterative processes. A unique database was designed to store fetal biometric and image data acquired as part of the Intergrowth-21st Consortium study. This database, which currently holds 50,000 fetal images through the course of gestation and from eight geographically diverse regions in the world, drives the proposed automated atlas construction methodology using local phase information to perform affine registration with normalized mutual information as the similarity parameter, followed by wavelet-based image fusion and averaging. The unique feature-based application of local phase and wavelet fusion towards creating the atlas reduces the intensity variations and difficulties in registering ultrasound images. The method is evaluated on fetal biparietal skull ultrasound images of 16, 21, and 33 weeks gestation. The results show that the proposed method is more robust to intensity variations than standard intensity-based methods. Results also suggest that the feature-based approach preserves much of the anatomical definition necessary in creating a clinically valid ultrasound image atlas.

7962-46, Session 9

Atlas selection strategy in multi-atlas segmentation propagation with locally weighted voting using diversity-based MMR reranking

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In multi-atlas based segmentation propagation, segmentations from multiple atlases are propagated to the target image and combined to produce the consensus segmentation result. Local weighted voting (LWV) method is a classifier fusion method which combines the propagated atlases using weighs obtained from local image similarities. We demonstrate that the segmentation accuracy using LWV improves as the number of atlases increases. Under this context, we show that introducing diversity in addition to image similarity by using maximal Marginal Relevance (MMR) criteria is a more efficient way to rank and select atlases. We test the method on a hippocampal atlas set of 138 normal control (NC) subjects and another set of 99 Alzheimer's disease patients provided by ADNI. The result shows that the proposed MMR reranking performed better than similarity based atlas selection when the same number of atlases were selected.

7962-47, Session 9

Multi-modal surface comparison and its application to intra-operatively acquired range data

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One of the main challenges related to image-guided interventions is the registration of pre-operative images with the patient's anatomy during the procedure. In this context, range imaging is gaining increasing attention for the purpose of acquiring intra-operative information about the morphology of the target organ(s). A novel, fast and, robust means for 3D surface acquisition are Time-of-Flight (ToF) cameras, which provide range images in addition to gray-scale intensity images with high update rates. For intra-operative registration purposes, these range images must be converted to surfaces and must be matched to pre-operatively acquired data. We present a framework for local and global multi-modal comparison of surfaces and we characterize the discrepancies between ToF and CT data in an in-vitro experiment. The framework

takes into account various aspects related to the surface characteristics and does not require high resolution input data in order to establish appropriate correspondences. We show that the presentation of local and global comparison data allows for an accurate assessment of ToF-CT discrepancies, and evaluate them according to the region of occurrence. The information gained from our study may be used for developing ToF pre-processing and matching algorithms or for improving calibration procedures for compensating systematic distance errors.

7962-48, Session 9

Distance transforms in multichannel MR image registration

M. Chen, A. Carass, J. Bogovic, P. Bazin, J. L. Prince, The Johns Hopkins Univ. (United States)

Deformable registration techniques play vital roles in a variety of medical imaging tasks such as image fusion, segmentation, and post-operative surgery assessment. In recent years, mutual information has become one of the most widely used similarity metrics for medical imaging registration algorithms. Unfortunately, as a matching criteria, mutual information loses much of its effectiveness when there is poor statistical consistency and a lack of structure. This is especially true in areas of images where the intensity is homogeneous and intensity information is sparse. Here we present a method designed to address this problem by integrating distance transforms of anatomical segmentations as part of a multi-channel mutual information framework within the registration algorithm. Our method was tested by registering real MR brain data and comparing the segmentation of the results against that of the target. Our analysis showed that by integrating distance transforms of the the white matter segmentation into the registration, the overall segmentation of the registration result was closer to the target than when the distance transform was not used.

7962-49, Session 9

Validation of histology image registration

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This work aims to validate a registration approach using a multi-modality fiducial marker, which is detectable in volumetric medical images as well as in histology and optical images of the paraffin blockface. A marker with these characteristics can be reliably used to validate the registration techniques which are intensity-based, shape-based, or based on intrinsic landmarks. These markers have also been used to correlate histology images with medical images using landmark-based registration techniques.

The present research reports on some initial results of the experiments that we have accomplished to validate a histology image registration pipeline.

After implanting the fiducial markers in a fixed xenograft of human breast cancer cell line (MDA) it is processed and histology sections are prepared. In this work 10 pairs of H&E and their correspondent blockface images were used to assess the proposed method. Since the blockface images are used as references and each histology image is registered to its correspondent blockface image. Initial registration is done using Fourier descriptors and Iterative Closest points refines the alignment. Finally thin-plate Splines approach is used to compensate the deformation of the sections. After registration Target Registration Error is measured based on the centroid of the fiducial markers.

7962-50, Session 10

Intensity inhomogeneity correction of magnetic resonance images using patches

S. Roy, A. Carass, P. Bazin, J. L. Prince, The Johns Hopkins Univ. (United States)

This paper presents a patch-based non-parametric approach to the correction of intensity inhomogeneity from magnetic resonance (MR) images of the human brain. During image acquisition, the inhomogeneity present in the radio-frequency coil, is usually manifested on the reconstructed MR image as a smooth shading effect. This artifact can significantly deterioratethe performance of any kind of image processing algorithm that uses intensities as a feature.

Most of the current inhomogeneity correction techniques use explicit smoothness assumptions on theinhomogeneity field, which sometimes limit their performance if the actual inhomogeneity is not so smooth, a problem that becomes prevalent in high fields. The proposed patch-based inhomogeneity correction method does not assume any parametric smoothness model, instead, it uses patches from an atlas of an inhomogeneity-free image to do the correction. Preliminary results show that the proposed method is comparable to a current state of the art method, a non-parametric non-uniform intensity normalization (N3), on images having smooth inhomogeneity field, and outperforms it when the inhomogeneity is not smooth.

7962-51, Session 10

Initial evaluation of virtual un-enhanced imaging derived from fast kVp-switching dual energy contrast enhanced CT for the abdomen

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The feasibility and utility of creating virtual un-enhanced images from contrast enhanced data acquired using a fast switching dual energy CT acquisition, is explored. Utilizing projection based material decomposition data, monochromatic images are generated and a Multi-material decomposition technique is applied. Quantitative and qualitative evaluation is performed to assess the equivalence of Virtual Un-Enhanced (VUE) and True Un-enhanced (TUE) for multiple tissue types and different organs in the abdomen. Ten patient cases were analyzed where a TUE and a subsequent Contrast Enhanced (CE) acquisition were obtained using fast kVp-switching dual energy CT utilizing Gemstone Spectral Imaging. Quantitative measurements were made by placing multiple regions of interest (ROI) on the different tissues and organs in both the TUE and VUE images. The absolute Hounsfield Unit (HU) differences in the ROI means between TUE and VUE were measured along with tdifferences of the standard deviations. Qualitative evaluation was performed by two radiologists for overall image quality, presence of residual contrast, appearance of pathology, appearance and contrast of normal tissues and organs in comparison to TUE. A very strong correlation was observed between the TUE and VUE images in both quantitative and qualitative evaluations.

7962-52, Session 10

A neural network learned information theoretic measure for heart motion abnormality detection

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Western Ontario (Canada); T. Peters, Robarts Research Institute (Canada); S. Li, Lawson Health Research Institute (Canada)

We propose an information theoretic neural network for normal/abnormal left ventricular motion classification which outperforms significantly other recent methods in the literature. The proposed framework consists of a supervised 3-layer artificial neural network (ANN) which uses hyperbolic tangent sigmoid and linear transfer functions for hidden and output layers, respectively. The ANN is fed by information theoretic measures of left ventricular wall motion such as Shannon's differential entropy (SDE), R´enyi entropy and Fisher information, which measure global information of subject's distribution. Moreover, the ANN structure was subject to modifications of number of layers, nodes and activation function to give the best performance. Using 395×20 segmented LV cavities of short-axis magnetic resonance images (MRI) acquired from 48 subjects, the experimental results show that the proposed method outperforms Support Vector Machine and thresholding based information theoretic classifiers. It yields a specificity equal to 90%, a sensitivity of 91%, and a remarkable Area Under Curve for Receiver Operating Characteristic (ROC), equal to 93.2%.

7962-53, Session 10

Content-based image retrieval utilizing shape modeling and manifold learning

R. E. Sparks, A. Madabhushi, Rutgers, The State Univ. of New Jersey (United States)

Automated content-based image retrieval (CBIR) can aid in efficient retrieval of images in large medical databases. In this paper we present a morphometric-based CBIR system to determine image similarity in three datasets: the synthetic MPEG-7 Set B, DCE-MRI of suspicious breast lesions, and prostate histopathology. We determine morphometric similarity by Explicit Shape Descriptors (ESDs) which are obtained from a pairwise comparisons between medial axis shape models and nonlinear dimensionality reduction to determine relevant morphometric differences. For the synthetic MPEG-7 Set B containing 1400 images in 70 classes we obtain an area under the precision-recall curve (AUPRC) of 0.83 ± 0.15. ESD-based CBIR is better able to return relevant images in a 44 image dataset of breast DCE-MRI than common morphometric features, which have an AUPRC of 0.49 ± 0.02 for benign breast lesions and 0.55 ± 0.02 for malignant breast lesions. AUPRC for the prostate histopathology datasets is from 0.42 to 0.50 for 888 glands across three Gleason grades. Our ESDs represent a powerful way to represent morphometric features across many objects.

7962-170, Session 10

Amplitude remapping as a step towards standardizing the analysis of MR-images

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We investigate the utility of amplitude remapping of magnetic resonance (MR)-images for making the analysis of such images more independent of the MR-device, the selected sequence, and its

parameters. To this end, we analyze the morphological structure of trabecular bones using weighted scaling indices and Minkowski functionals in the context of osteoporosis. After remapping the amplitude distribution of MR-images onto a normal distribution with zero mean and unit variance, we study how the diagnostic performance of the structure measures is affected by this remapping. The diagnostic performance of the scaling index method is stable under the remapping for both spin echo (SE) and gradient echo (GE) sequences: The area under curve (AUC) value from the ROC analysis changes only slightly from 0.76 (original image) to 0.74 (remapped image) for the SE sequence and from 0.78 to 0.77 for the GE sequence. For the Minkowski functionals, the diagnostic performance suffers significantly for the SE sequence, whereas it is much more robust for the GE sequence. Therefore, the scaling index method should be the method of choice when analyzing MR-images after amplitude remapping.

We also find that in the scaling index analysis, the remapping makes the results much more consistent between the SE and the GE sequence by bringing the histograms of the scaling indices closer together. Thus, the amplitude remapping can be used as a first step to standardize the scaling index analysis between different sequences of an MRI device.

7962-55, Session 11

Machine learning based vesselness measurement for coronary artery segmentation in cardiac CT volumes

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Various coronary artery segmentation methods have been proposed and most of them are based on shortest path computation given one or two end points on the artery. The major variation of the shortest path based approaches is in the different vesselness measurements used for the path cost. An empirically designed measurement (e.g., the widely used Hessian vesselness measurement) is by no means optimal in the use of image context information. In this paper, a machine learning based vesselness measurement is proposed by exploiting the rich domain specific knowledge embedded in an expert-annotated dataset. For each voxel, we extract a set of geometric and image features. The probabilistic boosting tree (PBT) is then used to train a classifier, which assigns a high score for voxels inside the artery and a low score to those outside. The detection score can be treated as a vesselness measurement in the computation of the shortest path. To speed up the system, we perform classification only for voxels around the heart surface, which is achieved by automatically segmenting the whole heart from the 3D volume in a preprocessing step. Experiments demonstrate that the proposed learning based vesselness measurement outperforms the conventional Hessian vesselness in both speed and accuracy.

7962-56, Session 11

Automated vasculature extraction from placenta images

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Recent research in perinatal pathology argues that analyzing properties of the placenta may reveal important information on how certain diseases progress. Understanding placental vasculature can help doctors identify where prenatal development diverged from normality. This could potentially help lead to earlier diagnoses of significant life-long diseases. An essential step in the analysis of the vascular network pattern is the extraction of the blood vessels, which has only been done manually through a costly and time-consuming process. There is no existing method to automatically detect placental blood vessels; in addition, the large variation in shape, color, and texture of the placenta makes it difficult to apply standard edge-detection algorithms. We describe a method to automatically detect and extract blood vessels from a given

image by using image processing techniques and neural networks. We evaluate several local features for every pixel, combined with a novel modification to an existing road detector.

7962-57, Session 11

Level set based vessel segmentation accelerated with periodic monotonic speed function

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To accelerate level set based abdominal aorta segmentation on CTA data, we propose a periodic monotonic speed function, which allows segments of the contour to expand within one period and to shrink in the next period. This strategy avoids the contour's local wiggling behavior which often occurs during the propagating when certain points move faster than the neighbors, as the curvature force will move them backwards even though the whole neighborhood will eventually move forwards. Using the periodic monotonic speed function, these faster points will, instead, stay in their places waiting for the neighbors to catch up. A period ends when all the expanding/shrinking segments can no longer expand/shrink, which in most cases means that they have reached the border of the vessel. This periodic monotonic speed function also allows us to implement a lazy narrow band level set algorithm which prevents the endless computation on the points that have reached the vessel border. As those points' expanding/shrinking trend changes just after several iterations, in the rest iterations of one period the computation can focus on the actual growing parts. Finally, a new convergence detection method is used to permanently stop updating the local level set function when the zero level set is stationary on a voxel for several periods. The segmentation stops naturally when all points on the contour are stationary. In our preliminary experiments, significant speedup (about 10 times) was achieved on 3D data without losing the segmentation accuracy.

7962-58, Session 11

Multispectral MRI centerline tracking in carotid arteries

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We propose a method to track the centerlines for internal and external carotid arteries using a Minimum Cost Path approach with two user defined seed points. The cost image of the Minimum Cost Path is based on both vessel medialness and lumen intensity similarity in two MR images: Black Blood MRA and Phase Contrast MRA. After intensity inhomogeneity correction and noise reduction, the two images are aligned using affine registration. The two parameters that control the steepness of the cost image were determined in an optimization experiment on 40 training datasets. Experiments on the training datasets also showed that the combination of gradient-based medialness and lumen intensity similarity in a cost function increases the tracking accuracy compared to using only one of these components. Furthermore, centerline tracking using both MRA sequences outperformed tracking using only one of these MRA images. In the testing set of 152 images from 38 patients, 148 centerlines were successfully extracted using the parameters optimized in the training datasets. The average mean distance to the reference standard, the manual annotated centerlines, was 0.98 mm, which is comparable to the in plane resolution. This indicates that the proposed method has high potential to replace the manual centerline annotation.

7962-59, Session 11

CARES--completely automated robust edge snapper for carotid ultrasound IMT measurement on a multi-institutional database of 300 images: a two stage system combining An intensity-based feature approach with first order absolute moments

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The carotid intima-media thickness (IMT) is the most used marker of progression of atherosclerosis and onset of cardiovascular diseases. Computer-aided measurements improve accuracy, but usually require user interaction.

In this paper we characterized a new and completely automated technique for carotid segmentation and IMT measurement based on the merits of two previously developed techniques. We used an integrated approach of intelligent image feature extraction and line fitting for automatically locating the carotid artery in the image frame, followed by wall interfaces extraction based on Gaussian edge operator. We called this as CARES.

We validated the CARES on a multi-institutional database of 300 carotid ultrasound images. IMT measurement bias was 0.032 ± 0.141 mm, comparable to that of user-driven methodologies and suitable to clinical use. We benchmarked, CARES with the previously developed completely automated method (named CALEX) by the same authors, and found that CARES outperformed CALEX by reducing measurement error of about 67%. Our novel approach of CARES could not process 12 images out of 300 (4%) since carotid location failed.

CARES ensured complete automation and high accuracy in IMT measurement; hence it could be a suitable tool for processing of large datasets in multicenter studies on atherosclerosis.

7962-60, Session 11

Gradient-based 3D-2D registration of cerebral angiograms

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Endovascular treatment of cerebral aneurysms and arteriovenous malformations (AVM) involves navigation of a catheter through the femoral artery and vascular system into the brain and into the aneurysm or AVM. Intra-interventional navigation utilizes digital subtraction angiography (DSA) to visualize vascular structures and X-ray fluoroscopy to localize the endovascular components. Due to the two-dimensional (2D) nature of the intra-interventional images, navigation through a complex three-dimensional (3D) structure is a demanding task. Registration of pre-interventional MRA, CTA, or 3D-DSA images and intra-interventional 2D DSA images can greatly enhance visualization and navigation. As a consequence of better navigation in 3D, the amount of required contrast medium and absorbed dose could be significantly reduced. In the past, development and evaluation of 3D-2D registration methods received considerable attention. Several validation image databases and evaluation criteria were created and made publicly available. However, applications of 3D-2D registration methods to cerebral angiograms and their validation are rather scarce. In this paper,

the 3D-2D robust gradient reconstruction-based (RGRB) registration algorithm is applied to CTA and DSA images and analyzed. For the evaluation purposes five image datasets, each comprised of a 3D CTA and several 2D DSA-like digitally reconstructed radiographs (DRRs) generated from the CTA, with accurate gold standard registrations were created. A total of 4000 registrations on these five datasets resulted in mean mTRE values between 0.07 and 0.59 mm, capture ranges between 6 and 11 mm and success rates between 61 and 88% using a failure threshold of 2 mm.

Conference 7963: Computer-Aided Diagnosis

Tuesday-Thursday 15-17 February 2011 • Part of Proceedings of SPIE Vol. 7963
Medical Imaging 2011: Computer-Aided Diagnosis

7963-01, Session 1

CAD: if the world is close to ideal

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Computer-aided diagnosis (CAD) is an expanding field in the past few decades. In the early applications, CAD was designed mostly to analyze patient and clinical data and to generate patient-specific advice for health care purposes. As medical images in digital form became more commonly available, image analysis has provided a main source of information for CAD, be it for detection or diagnosis. CAD research has extended from mammography to other breast imaging modalities, and from breast, lung to many other organs. However, only a small number of CAD systems have been approved by FDA for clinical use to-date. To bring a CAD system from the laboratory to the clinic, the CAD system has to undergo rigorous training and testing to ensure its generalizability to the patient population. Both the standalone performance and the potential influence of the CAD system on radiologists' performance have to be properly assessed. An important but currently ignored issue is the quality assurance of a CAD system after its acceptance into clinical use. The standalone performance of a CAD system should be evaluated periodically to assure its accuracy and consistency in the clinical environment. The sensitivity and specificity of radiologists using the CAD system in routine clinical settings should be made more easily traceable and the performance data should be analyzed with appropriate methodologies. The periodic feedback to radiologists will increase their understanding of the capability and the limitations of CAD, which, in turn, may improve the effectiveness of their utilization of CAD information in patient care. The proper use and understanding of the impact of CAD in clinical practice may not only increase the confidence of radiologists and the scientific communities in CAD but also stimulate further research and development of CAD in the existing and new areas. Future efforts in CAD should direct not only to technological development but also to the design of practical methods for assessment and monitoring of CAD performance and radiologist-CAD interaction in routine clinical environment. These issues will be discussed, together with a summary of the related opinions from the AAPM CAD Subcommittee.

7963-02, Session 1

Automatic lumbar vertebra segmentation from clinical CT for wedge compression fracture diagnosis

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Lumbar vertebral fractures greatly vary in types and causes. They result from severe traumatic or pathological conditions such as Osteoporosis. Lumbar wedge compression fractures are among the most common ones where the vertebrae is severely compressed forming a wedge shape and causing pain and pressure on the nerve roots and the spine. Vertebral segmentation is the first step in any automated diagnosis task. To that end, we present a fully automated method for robustly localizing and segmenting the vertebrae for preparation of vertebral fracture diagnosis. We also present preliminary promising feature extraction for wedge fracture diagnosis. our method consists of four main steps: 1)Localization of the discs. 2) Detection of the vertebral body ROI. 3) Separating out the five vertebra. and 4) Obtaining vertebrae points of interest by curve fitting and geometric operations. our segmentation results are promising with an average error of 1.7 mm on 20 clinical CT volumes.

7963-03, Session 1

Lumbar spinal stenosis CAD from clinical MRM and MRI based on inter- and intra-context features with a two-level classifier

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An imaging test has an important role in the diagnosis of lumbar abnormalities since it allows to examine the internal structure of soft tissues and bony elements without the need of an unnecessary surgery and recovery time. For the past decade, among various imaging modalities, magnetic resonance imaging (MRI) has taken the significant part of the clinical evaluation of the lumbar spine. This is mainly due to technological advancements that lead to the improvement of imaging devices in spatial resolution, contrast resolution, and multi-planar capabilities. In addition, noninvasive nature of MRI makes it easy to diagnose many common causes of low back pain such as disk herniation, spinal stenosis, and degenerative disk diseases. In this paper, we propose a method to diagnose lumbar spinal stenosis (LSS), a narrowing of the spinal canal, from magnetic resonance myelography (MRM) images. Our method segments the thecal sac in the preprocessing stage, generates the features based on inter- and intra-context information, and diagnoses lumbar disc stenosis. Experiments with 55 subjects show that our method achieves 91% diagnostic accuracy. In the future, we plan to test our method on more subjects.

7963-04, Session 2

Spectral embedding based active contour (SEAC): application to breast lesion segmentation on DCE-MRI

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Spectral embedding (SE), a graph-based manifold learning method, has previously been shown to be useful in high dimensional data classification. In this work, we present a novel scheme for an SE based active contour (SEAC) segmentation scheme. The motivation behind the use of SE is that it provides an orthogonal eigenvector-based data representation, allowing for computation of strong tensor gradients that serve as an optimal stopping criterion for the active contour model. On a total of 50 breast DCE-MRI studies, we quantitatively and qualitatively demonstrate that SEAC accurately segments the lesion of interest with a mean absolute distance (MAD) of 3.2 +/- 2.1 pixels and mean Dice similarity coefficient (DSC) of 0.74 +/- 0.13 compared to the manual segmentation whereas the active contour in conjunction with fuzzy c-means, a commonly used segmentation method for breast DCE-MRI, produced a MAD of 7.2 +/- 7.4 pixels and mean DSC of 0.58 +/- 0.32 compared to manual segmentation.

7963-05, Session 2

Estimating corresponding locations in ipsilateral breast tomosynthesis views

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To improve cancer detection in mammography, breast exams usually consist of two views per breast. To combine information from both views, radiologists and multiview computer-aided detection (CAD) systems need to match corresponding regions in the two views. In digital breast tomosynthesis (DBT), finding corresponding regions in ipsilateral volumes may be a difficult and time-consuming task for radiologists, because many slices have to be inspected individually. In this study we developed a method to quickly estimate corresponding locations in ipsilateral tomosynthesis views by applying a mathematical transformation. First a compressed breast model is matched to the tomosynthesis view containing a point of interest. Then we decompress, rotate and compress again to estimate the location of the corresponding point in the ipsilateral view. In this study we use a simple elastically deformable sphere model to obtain an analytical solution for the transformation in a given DBT case. The model is matched to the volume by using automatic segmentation of the pectoral muscle, breast tissue and nipple. For validation we annotated 181 landmarks in both views and applied our method to each location. Results show a median 3D distance between the actual location and estimated location of 1.5 cm; a good starting point for a feature based local search method to link lesions for a multiview CAD system. Half of the estimated locations were less than 1 slice away from the actual location, making our method useful as a tool in mammographic workstations to interactively find corresponding locations in ipsilateral tomosynthesis views.

7963-06, Session 2

Automatic breast density segmentation: an integration of different approaches

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Mammographic breast density has been found to be a strong risk factor for breast cancer. In most studies it is assessed with a user assisted threshold method, which is time consuming and subjective. In this study we develop a breast density segmentation method that is fully automatic.

The method is based on pixel classification in which different approaches known in literature to segment breast density are integrated and extended. In addition the method incorporates knowledge of a trained observer, by using segmentations obtained by the user assisted threshold method as training data. The method was trained and tested on 1300 digitised screen film mammographic images. Results showed a high correspondence between the automated method and the user assisted threshold method. The correlation coefficient between our method and the user assisted method was R = 0.884 for percent density, which is substantially higher than the best correlation found in literature (R=0.70). The AUC obtained when discriminating between fatty and dense pixels was 0.984. A combination of segmentation strategies outperformed the application of a single segmentation technique. The method was shown to be robust for differences in mammography systems, image acquisition techniques and image quality.

7963-07, Session 2

Detection of architectural distortion in prior mammograms using measures of angular distribution

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We present methods for the detection of architectural distortion in mammograms of interval-cancer cases taken prior to the diagnosis of breast cancer using measures of angular distribution of Gabor filter response in magnitude and angle, coherence, orientation strength, and the angular spread of power in the Fourier spectrum. A total of 4224 regions of interest (ROIs) were automatically obtained using Gabor filters and phase portrait analysis from 106 prior mammograms of 56 interval-cancer cases with 301 ROIs related to architectural distortion, and from 52 mammograms of 13 normal cases. Images of coherence and orientation strength were derived from the Gabor responses in magnitude and orientation. Each ROI was represented by the entropy of the angular histogram composed with the Gabor magnitude response, angle, coherence, and orientation strength; the entropy of the angular spread of power in the Fourier spectrum was also computed. Using stepwise logistic regression for feature selection and the leave-one-image-out method in feature selection and pattern classification, the area under the receiver operating characteristics curve of 0.76 was obtained with an artificial neural network based on radial basis functions. Analysis of the free-response receiver operating characteristics indicated 82% sensitivity at 7.2 false positives per image.

7963-08, Session 2

Fully automated segmentation of the pectoralis muscle boundary in breast MR images

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Dynamic Contrast Enhanced MRI (DCE-MRI) of the breast is emerging as a novel tool for early tumor detection and diagnosis. The segmentation of the structures in breast DCE-MR images, such as the nipple, the breast-air boundary and the pectoralis muscle, serves as a fundamental step for further computer assisted diagnosis (CAD) applications, e.g. breast density analysis. Moreover, the previous clinical studies show that the distance between the posterior breast lesions and the pectoralis muscle can be used to assess the extent of the disease. To enable automatic quantification of the distance from a breast tumor to the pectoralis muscle, a precise delineation of the pectoralis muscle boundary is required. We present a fully automatic segmentation method based on the second derivative information represented by the Hessian matrix. The voxels proximal to the pectoralis muscle boundary exhibit roughly the same Eigen value patterns as a sheet-like object in 3D, which can be enhanced and segmented by a Hessian-based sheetness filter. A vector-based connected component filter is then utilized such that only the pectoralis muscle is preserved by extracting the largest connected component. The proposed method was evaluated quantitatively with a test data set which includes 30 breast MR images by measuring the average distances between the segmented boundary and the annotated surfaces in two ground truth sets, and the statistics showed that the mean distance was 1.434 mm with the standard deviation of 0.4661 mm, which shows great potential for integration of the approach in the clinical routine.

7963-09, Session 2

Multi-view information fusion for automatic BI-RADS description of mammographic masses

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Most CBIR-based CAD systems (Content Based Image Retrieval systems for Computer Aided Diagnosis) identify lesions that are eventually relevant. These systems base their analysis upon a single independent view. This article presents a CBIR framework which automatically describes mammographic masses with the BI-RADS lexicon, fusing information from the two mammographic views. After an expert selects a Region of Interest (RoI) at the two views, a CBIR strategy searches similar masses in the database by automatically computing the Mahalanobis distance between shape and texture feature vectors of

the mammography. The strategy was assessed in a set of 400 cases, for which the suggested descriptions were compared with the ground truth provided by the data base. Two information fusion strategies were evaluated, allowing a retrieval precision rate of 89.6% in the best scheme. Likewise, the best performance obtained for shape, margin and pathology description, using a ROC methodology, was reported as AUC = 0.86, AUC = 0.72 and AUC = 0.85, respectively.

7963-10, Session 3

A CAD system for automatic detection and identification of solitary pulmonary nodules on follow-up CT scans based on local intensity structure analysis and non-rigid image registration

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This paper presents a new CAD (Computer Aided Diagnosis) system that can automatically detect solitary pulmonary nodule (SPN) and identify such detected nodules on follow-up thoracic CT scans. Due to the clinical importance, a physician needs to find the lung nodules on chest CT and observe their progress over time in order to diagnose whether it is benign or malignant, or to observe the effect of chemotherapy for malignant ones using follow-up data. However, the enormous amount of CT images makes large burden tasks to a physician. In order to lighten this burden, we aim to develop a system for automatic detection and assisting observation of SPNs in follow-up CT scans. Firstly, we detect nodules from all of the input 3D thoracic CT scans based on local intensity structure analysis. Then we co-register follow-up CT scans based on non-rigid registration to find the correspondence of nodules that are automatically detected in each CT scan. Finally, we assign an unique ID to corresponding nodules and visualize the result. We applied these methods to three patients including 14 thoracic CT scans. Our nodule detection method detected 90% of SPNs from the whole images, and the registration technique found 83:3% correspondences from detected nodules. The results confirmed our system is feasible for detecting and identifying nodules on follow-up CT scans.

7963-11, Session 3

Improved computerized detection of lung nodules in chest radiographs by means of 'virtual dual-energy' radiography

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Major challenges in current computer-aided detection (CADe) of nodules in chest radiographs (CXRs) are to detect nodules that overlap with ribs and to reduce the frequent false positives (FPs) caused by ribs. Our purpose was to develop a CADe scheme with improved sensitivity and specificity by use of "virtual dual-energy" (VDE) CXRs where ribs are suppressed with a massive-training artificial neural network (MTANN). To reduce rib-induced FPs and detect nodules overlapping with ribs, we incorporated VDE technology in our CADe scheme. VDE technology suppressed ribs in CXR while maintaining soft-tissue opacity by use of an MTANN that had been trained with real DE imaging. Our scheme detected nodule candidates on VDE images by use of a morphologic filtering technique. Sixty-four morphologic and gray-level-based features were extracted from each candidate from both original and VDE CXRs. A nonlinear support vector classifier was employed for classification of the nodule candidates. A publicly available database containing 126 nodules in 126 CXRs was used for testing of our CADe scheme. Twenty nine percent (36/126) of the nodules were rated "extremely subtle" or "very subtle" by a radiologist. With the original scheme, a sensitivity of 76.2 (96/126) with 5 (630/126) FPs per image was achieved. By use of VDE images, more nodules overlapping with ribs were detected and the sensitivity was improved substantially to 84.1% (106/126) at the same FP rate in a leave-one-out cross-validation test, whereas the literature shows that other CADe schemes achieved sensitivities of 66.0% and 72.0% at the same FP rate.

7963-12, Session 3

Evaluation of 1D, 2D and 3D nodule size estimation by radiologists for spherical and nonspherical nodules through CT thoracic phantom imaging

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The purpose of this work was to estimate bias in measuring the size of spherical and non-spherical lesions by radiologists using three sizing techniques under a variety of simulated lesion and reconstruction slice thickness conditions. We conducted a reader study in which 6 radiologists estimated the size of 10 synthetic nodules of various sizes, shapes and densities embedded within a realistic anthropomorphic thorax phantom from CT scan data. Two repeat CT scans of the phantom containing each nodule were acquired using a Philips 16-slice scanner at a 0.8 and 5 mm slice thickness. The readers measured the sizes of all nodules for each of the 40 resulting scans (10 nodules x 2 slice thickness x 2 repeat scans) using three sizing techniques (1D longest in-slice dimension; 2D area from longest in-slice dimension and corresponding longest perpendicular dimension; 3D semi-automated volume) in each of 2 reading sessions. The normalized size was estimated for each sizing method and an inter-comparison of bias among methods was performed. The overall relative biases (standard deviation) of the 1D, 2D and 3D methods were -14.6 (20.4), -18.8 (28.3) and -1.3 (21.9) percentage points, respectively. The relative biases of 1D, 2D, and 3D were significantly different ($p<0.001$ for all pairings). Nodule shape, density, and slice thickness were found to be significant effects. 3D volume reader measurements on thin slice images showed the least bias across nodule shapes/densities. This may have significant implications for standardizing volumetric image analysis using CT in settings such as clinical trials.

7963-13, Session 3

Automatic lung nodule detection in thick slice CT: a comparative study of different gating schemes in CAD

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Common chest CT clinical workflows for detecting lung nodules use a large slice thickness protocol (typically 5mm). However, most existing CAD studies are performed on a thin slice data (0.3-2mm) available on state-of-the art scanners. A major challenge for the widespread clinical use of Lung CAD is the concurrent availability of both thick and thin

resolutions for use by radiologist and CAD respectively. Having both slice thickness reconstructions is not always possible based on the availability of scanner technologies, acquisition parameters chosen at remote site, and transmission and archiving constraints that make transmission and storage of large data impracticable. However, applying current thin-slice CAD algorithms on thick slice cases outside their designed acquisition parameters may result in degradation of sensitivity and high false-positive rate making them clinically unacceptable. Therefore a CAD system that can handle thicker slice acquisitions is desirable to address those situations.

In this paper, we propose a CAD system which works directly on thick slice scans. We first propose a multi-stage classifier based CAD system for detecting lung nodules in such type of data. Furthermore, we propose different gating systems adapted for thick slice scans. The proposed gating schemes are based on: 1. wall-attached and rest of the nodules. 2. central and non-central region. These gating schemes can be used independently or can be combined as well. Preliminary results showing significant improvement of CAD sensitivity at much better false positive rate on thick-slice CT images are presented.

7963-14, Session 3

Temporal subtraction of 'virtual dual-energy' chest radiographs for improved conspicuity of growing cancers and other pathologic changes

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A temporal-subtraction (TS) technique provides enhanced visualization of tumor growth and subtle pathologic changes between previous and current chest radiographs (CXRs) from the same patient. Our purpose was to develop a new TS technique incorporating "virtual dual-energy" technology to improve its enhancement quality. Our TS technique consisted of ribcage edge detection, rigid body transformation based on a global alignment criterion, image warping under the maximum cross-correlation criterion, and subtraction between the registered previous and current images. A major problem with TS was obscuration of abnormalities by rib artifacts due to misregistration. To reduce the rib artifacts, we developed a massive-training artificial neural network (MTANN) for separation of ribs from soft tissue. The MTANN was trained with input CXRs and the corresponding "teaching" soft-tissue CXRs obtained with real dual-energy radiography. Once trained, the MTANNs did not require a dual-energy system and provided "soft-tissue" images. Our database consisted of 100 sequential pairs of CXR studies from 53 patients. To assess the registration accuracy and clinical utility, a chest radiologist subjectively rated original TS and rib-suppressed TS images on a 5-point scale. By use of "virtual dual-energy" technology, rib artifacts in the TS images were reduced substantially. The registration accuracy and clinical utility ratings for TS rib-suppressed images (3.7; 3.9) were significantly better than those for original TS images (3.5; 3.6) ($P<0.01$; $P<0.02$, respectively). Our "Virtual dual-energy" TS CXRs can provide the improved enhancement quality of TS images for the assessment of pathologic change.

7963-15, Session 4

Segmentation of the lumen and media-adventitia boundaries of the common carotid artery from 3D ultrasound images

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Three-dimensional ultrasound (3D US) vessel wall volume (VWV) measurements provide high measurement sensitivity and reproducibility for the monitoring and assessment of carotid atherosclerosis. In this paper, we describe a semi-automated approach based on the level set method to delineate the media-adventitia and lumen boundaries of the common carotid artery from 3D US images to support the computation of VWV. Due to the presence of plaque and US image artifacts, the carotid arteries are challenging to segment using image information alone. Our segmentation framework combines several image cues with domain knowledge and limited user interaction. Our method was evaluated with respect to manually outlined boundaries on 430 2D US images extracted from 3D US images of 30 patients who have carotid stenosis of 60% or more. The VWV given by our method differed from that given by manual segmentation by 6.7% ± 5.0%. For the media-adventitia and lumen segmentations, respectively, our method yielded Dice coefficients of 95.2% ± 1.6%, 94.3% ± 2.6%, mean absolute distances of 0.3 ± 0.1 mm, 0.2 ± 0.1 mm, maximum absolute distances of 0.8 ± 0.4 mm, 0.6 ± 0.3 mm, and volume differences of 4.2% ± 3.1%, 3.4% ± 2.6%. The realization of a semi-automated segmentation method will accelerate the translation of 3D carotid US to clinical care for the rapid, non-invasive, and economical monitoring of atherosclerotic disease progression and regression during therapy.

7963-16, Session 4

Feature extraction and wall motion classification of 2D stress echocardiography with support vector machines

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Stress echocardiography is a common clinical procedure for diagnosing heart disease. Clinically, diagnosis of the heart wall motion depends mostly on visual assessment, which is highly subjective and operator-dependent. Introduction of automated methods for heart function assessment have the potential to minimise the variance in operator assessment. Automated wall motion analysis consists of two main steps (i) segmentation of heart wall borders, and (ii) classification of heart function as either "normal" or "abnormal" based on the segmentation. This paper considers automated classification of rest and stress echocardiography. Most previous approaches to the classification of heart function have considered rest or stress data separately, and have only considered using features extracted from the two main frames (corresponding to the end-diastole and end-systole). One previous attempt [Mansor, Hughes, Noble] has been made to combine information from rest and stress sequences utilising a Hidden Markov Model (HMM), which has proven to be the best performing approach to date. Here, we propose a novel alternative feature selection approach using combined information from rest and stress sequences for motion classification of stress echocardiography, utilising a Support Vector Machines (SVM) classifier. We describe how the proposed SVM method overcomes difficulties that occur with HMM classification. Overall accuracy with the new method for global wall motion classification using datasets from 173 patients is 92.47%, and the accuracy of local wall motion classification is 87.20%, showing that the proposed method outperforms the current state-of-the-art HMM-based approach (for which global and local classification accuracy is 82.15% and 78.33%, respectively).

7963-17, Session 4

Automated method for the identification and analysis of vascular tree structures in retinal vessel network

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Systemic diseases and retinopathies are known to affect the course and morphological properties of retinal blood vessels, i.e. change in shape, caliber, branching pattern and tortuosity. The response of arteries and veins to these changes may be different, depending upon the nature of

retinopathy. Analysis of morphologic changes which may be prominent either to an artery or a vein may indicate symptoms describing the early occurrence of a particular retinopathy.

Hence, the identification and structural mapping of retinal vessel trees in two dimensional color fundus images may be helpful for artery-venous distinction and allows quantitative analysis of morphologic properties, specific to arteries or veins. We propose a method for structural mapping of the vessel trees, with graph search and mathematical morphology based approach. An automated technique analyzes the vascular network to label each individual primary vessel, corresponding branches, and spatial positions of branching points and cross-over points. Structural separation of retinal vessel trees may help in a more robust classification of arteries and veins, compared to the previously published methods based on localized analysis. This information is provided as an input to the quantitative morphology assessment algorithm.

We applied structural mapping method to a dataset of 15 fundus images, resulting in accuracy of 92.87% correctly assigned vessel pixels, when compared with the gold standard. Accordingly, the structural mapping performs well and we are currently studying its potential in evaluating abnormal arterial or venous patterns which may be helpful in diagnosing the diseases such as diabetic retinopathy and retinopathy of prematurity.

7963-18, Session 4

Robust and fast abdominal aortic aneurysm centerline detection for rupture risk prediction

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This work describes a robust and fast semi-automatic Abdominal Aortic Aneurysm (AAA) centerline detection approach. AAA is a vascular disease accompanied with progressive enlargement of the abdominal aorta, which leads to rupture if untreated, an event that accounts for the 13th leading cause of death in the U.S. The lumen centerline can be used to provide the initial starting points for thrombus segmentation. Different from other methods, which are mostly based on region growing and suffer from problems of leakage and heavy computational burden, we propose a novel method based on online classification. An online version of the adaboost classifier based on steerable features is applied to AAA MRI data sets with a rectangular box enclosing the lumen in the first slice. The classifier is updated during the tracking process by using the testing result of the previous slice as the new training data. Different from traditional offline versions, the online classifier can adjust weak leaner selectors automatically. With the help of integral images on the computation of haar-like steerable features, the method can achieve nearly real time processing (about 2 seconds per slice on a standard workstation). Ten ruptured and ten unruptured AAA data sets were processed and the tortuosity of the 20 centerlines was calculated. The correlation coefficient of the tortuosity was calculated to illustrate the significance of the prediction with the proposed method. The average error is approximately 2 voxels when compared to a manual segmentation procedure. The correlation coefficient is 0.386.

7963-19, Session 4

Machine learning based automatic detection of pulmonary trunk

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Pulmonary embolism is a common cardiovascular emergency with about 600,000 cases occurring annually and causing approximately 200,000 deaths in the US. CT pulmonary angiography (CTPA) has become the reference standard for PE diagnosis, but the interpretation of these large image datasets is made complex and time consuming by the intricate branching structure of the pulmonary vessels, a myriad of artifacts that may obscure or mimic PEs, and suboptimal bolus of contrast and inhomogeneities with the pulmonary arterial blood pool. To meet this challenge, several approaches for computer aided diagnosis of PE in CTPA have been proposed. However, none of these approaches is capable of detecting central PEs, distinguishing the pulmonary artery from the vein to effectively remove any false positives from the veins, and dynamically adapting to suboptimal contrast conditions associated the CTPA scans. To overcome these shortcomings, it requires highly efficient and accurate identification of the pulmonary trunk. For this very purpose, in this paper, we present a machine learning based approach for automatically detecting the pulmonary trunk. Our idea is to train a cascaded AdaBoost classifier with a large number of Haar features extracted from CTPA image samples, so that the pulmonary trunk can be automatically identified by sequentially scanning the CTPA images and classifying each encountered sub-image with the trained classifier. Our approach outperforms an existing anatomy-based approach, requiring no explicit representation of anatomical knowledge and achieving a nearly 100% accuracy tested on a large number of cases.

7963-20, Session 4

Computerized detection of pulmonary embolism in computed tomographic pulmonary angiography (CTPA): improvement of vessel segmentation

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Vessel segmentation is a fundamental step in an automated pulmonary embolism (PE) detection system. The purpose of this study is to improve the segmentation scheme for pulmonary vessels affected by PE and other lung diseases.

We have developed a multiscale hierarchical vessel enhancement and segmentation (MHES) method for pulmonary vessel tree extraction based on the analysis of eigenvalues of Hessian matrices. However, it is difficult to segment the pulmonary vessels accurately when the vessel is occluded by PEs and/or surrounded by lymphoid tissues or lung diseases. In this study, we developed a method that combines MHES with level set refinement (MHES-LSR) to improve vessel segmentation accuracy. The level set was designed to propagate the initial object contours to the regions with relatively high gray-level, high gradient, and high compactness as measured by the smoothness of the curvature along vessel boundaries.

Two and eight CTPA scans were randomly selected as training and test data sets, respectively. Forty volumes of interest (VOI) containing “representative” vessels were manually segmented by a radiologist experienced in CTPA interpretation and used as reference standard. The results show that, for the 32 test VOIs, the average percentage volume error relative to the reference standard was improved from 31.7±10.9% using the MHES method to 7.7±4.7% using the MHES-LSR method. The correlation between the computer-segmented vessel volume and the reference standard was improved from 0.954 to 0.986. The accuracy of vessel segmentation was improved significantly ($p<0.05$). The MHES-LSR method may have the potential to improve PE detection.

7963-21, Session 5

System for pathology categorization and retrieval in chest radiographs

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In this study we present an efficient image categorization and retrieval system applied to medical image databases, in particular large radiograph archives.

The methodology is based on local patch representation of the image content, using a bag of visual words approach and similarity-based

categorization with a kernel based SVM classifier.

We show an application to pathology-level categorization of chest x-ray data, the most popular examination in radiology. Our study deals with pathology detection and identification of individual pathologies including right and left pleural effusion, enlarged heart and cases of enlarged mediastinum. The input from a radiologist provided a global label for the entire image (healthy/pathology), and the categorization was conducted on the entire image, with no need for segmentation algorithms or any geometrical rules.

An automatic diagnostic-level categorization, even on such an elementary level as healthy vs pathological, provides a useful tool for radiologists on this popular and important examination.

This is a first step towards similarity-based categorization, which has a major clinical implications for computer-assisted diagnostics.

7963-22, Session 5

Search for the best matching ultrasound frame based on spatial and temporal saliencies

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In this paper we present a generic system for fast and accurate retrieval of the best matching frame from Ultrasound video clips given a reference Ultrasound image. It is challenging to build a generic system to handle various lesion types without any prior information of the anatomic structures of the Ultrasound data. We propose to solve the problem based on both spatial and temporal saliency maps calculated from the Ultrasound images, which implicitly analyze the semantics of images and emphasize the anatomic regions of interest. The spatial saliency map describes the importance of the pixels of the reference image while the temporal saliency map further distinguishes the subtle changes of the anatomic structure in a video. A hierarchical comparison scheme based on a novel similarity measure is employed to locate the most similar frames quickly and precisely. Our system ensures the robustness, accuracy and efficiency. Experiments show that our system achieves more accurate results with fast speed.

7963-23, Session 5

Optimized pathological and visual content-based neuroimaging retrieval

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Neuroimaging provides important insights for understanding neurobiology and is essential for accurate neurological and neurosurgical diagnosis and patient care. The volume and complexity of the neuroimaging datasets have greatly increased due to advances in scanning instrumentation. These large datasets now pose challenges for images retrieval / management and more effective approaches are needed. Content-based image retrieval (CBIR) takes advantage of the rich visual/physiological information in the images and can provide the opportunity for more efficient and reliable image retrieval. Although a number of investigators have used CBIR systems in neuroimaging, few of these approaches have explored all the potential features in these images. We suggest that such image retrieval could be optimized by using pathological and domain-specific visual features rather than texture features alone. We used the cerebral metabolic rate of glucose (CMRGlc) as the physiological parameter from static brain [ ] 2-fluorodeoxy-glucose (FDG) positron emission tomography (PET) images and a customized disorder-oriented mask (DOM) specific for a particular neurodegenerative disorder, with the regions of interest (ROIs) specific for each disease sub-type. We designed 8 Gabor filter banks with different parameter settings and identified the optimum Gabor function parameter setting for the visual feature extraction. Our experimental data indicate that optimization of the Gabor filter parameters, targeted to disease specific regions enhances retrieval precision.

7963-24, Session 5

Bone age assessment by content-based image retrieval and case-based reasoning

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Skeletal maturity is assessed by visual comparison of hand radiographs to a standardized reference image atlas. Most common are the methods by Greulich&Pyle and by Tanner&Whitehouse. For computer-aided diagnosis (CAD), local image regions of interest (ROI) such as the epiphysis or the carpal area are extracted and evaluated. Heuristic approaches trying to automatically extract, measure and classify bones and distances between bones suffer from the high variations in the imaged biological material and differences in age, gender and ethnic origin. As we have proven earlier, content-based image retrieval (CBIR) provides a robust solution without the need to delineate and measure bones. Epiphyseal ROIs (eROIS) of a hand radiograph are compared to previous cases with known age, mimicking a human observer. While we previously compared our results to the chronological patients' ages, we now present the more relevant performance relative to the bone age, as diagnosed by two independent radiologists. We conduct leaving-one-out experiments on 1,102 left hand radiographs and 15,428 metacarpal and phalangeal eROIs from the publicly available USC hand atlas. The similarity of the eROIs is assessed by cross-correlation of 16 x 16 scaled eROIs yielding a mean error rate of 0.99 years and a standard deviation of below 0.76 years. Furthermore, we introduce our publicly available online-demonstration system, where interested scientists and radiologists may either issue queries on the USC dataset or upload own radiographs for instant CAD. In future, we plan to evaluate physician with CBIR-CAD against physician without CBIR-CAD rather than physician vs. CBIR-CAD.

7963-25, Session 5

Integrating user profile in medical CBIR systems to answer perceptual similarity queries

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Techniques for Content-Based Image Retrieval (CBIR) have been intensively explored due to the increase in the amount of captured images and the need of fast retrieval of them. The medical field is a specific example that generates a large flow of information, especially digital images employed for diagnosing.

One issue that still remains unsolved deals with how to reach the perceptual similarity. That is, to achieve an effective retrieval, one must characterize and quantify the perceptual similarity regarding the specialist in the field.

Therefore, the present paper was conceived to fill in this gap creating a consistent support to perform similarity queries over medical images, maintaining the semantics of a given query desired by the user.

CBIR systems relying in relevance feedback techniques usually request the users to label relevant images. In this paper, we present a simple but highly effective strategy to survey user profiles, taking advantage of such labeling to implicitly gather the user perceptual similarity. The user profiles maintain the settings desired for each user, allowing tuning the similarity assessment, which encompasses dynamically changing the distance function employed through an interactive process.

Experiments using computed tomography lung images show that the proposed approach is effective in capturing the users' perception.

7963-26, Session 6

A method for mass candidate detection and an application to liver lesion detection

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Detection and segmentation of abnormal masses within organs in Computed Tomographic (CT) images of patients is of practical importance in computer-aided diagnosis (CAD), treatment planning, and analysis of normal as well as pathological regions. For intervention planning e.g. in radiotherapy the detection of abnormal masses is essential for patient diagnosis, personalized treatment choice and follow-up. The unpredictable nature of disease often makes the detection of the presence, appearance, shape, size and number of abnormal masses a challenging task, which is particularly tedious when performed by hand. Moreover, in cases in which the imaging protocol specifies the administration of a contrast agent, the contrast agent phases at which the patient images are acquired have a dramatic influence on the shape and appearance of the diseased masses. In this paper we propose a method to automatically detect candidate lesions (CLs) in 3D computer tomographic images, as well as its application to the detection of liver lesions. We introduce a novel multilevel candidate generation method that proves clearly advantageous in a comparative study with a state of the art approach. A learning-based selection module and a candidate fusion module are then introduced to reduce both redundancy and the false positive rate. The proposed workflow is applied to the detection of both hyperdense and hypodense hepatic lesions in all contrast agent phases, with resulting sensitivities of 89.7% and 92% and positive predictive values of 82.6% and 87.6% respectively.

7963-27, Session 6

Computer-aided detection of hepatocellular carcinoma in multiphase contrast-enhanced hepatic CT: a preliminary study

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Malignant liver tumors such as hepatocellular carcinoma (HCC) account for 1.25 million deaths each year worldwide. Early detection of HCC is sometimes difficult on CT images because the attenuation of HCC is often similar to that of normal liver parenchyma. Our purpose was to develop a computer-aided detection (CADe) of HCC using both arterial phase (AP) and portal-venous phase (PVP) of contrast-enhanced CT images. Our scheme consisted of liver segmentation, tumor candidate detection, feature extraction and selection, and classification of the candidates as HCC or non-lesions. We used a 3D geodesic-active-contour model coupled with a level-set algorithm to segment the liver. Both hyper- and hypo-dense tumors were enhanced by a sigmoid filter. A gradient-magnitude filter followed by a watershed algorithm was applied to the tumor-enhanced images for segmenting closed-contour regions as HCC candidates. Eighty morphologic and texture features were extracted from the segmented candidate regions in AP and PVP images. To select most discriminant features for classification, we developed a sequential forward and backward feature selection method directly coupled with a support vector machine (SVM) classifier. The initial CADe before the classification achieved a 100% (23/23) sensitivity with 33.7 (775/23) false positives (FPs) per patient. The SVM with four selected features removed 96.5% (748/775) of the FPs without any removal of the HCCs in a leave-one-lesion-out cross-validation test; thus, a 100% sensitivity with 1.2 FPs per patient was achieved, whereas CADe using AP alone produced 6.4 (147/23) FPs per patient at the same sensitivity level.

7963-28, Session 6

Automatic computer aided detection of abnormalities in multi-parametric prostate MRI

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Development of CAD systems for detection of prostate cancer has been a recent topic of research. A multi-stage computer aided detection scheme is proposed to help reduce perception and oversight errors in multi-parametric prostate cancer screening MRI. In addition, important features for development of computer aided detection systems for prostate cancer screening MRI are identified. A fast, robust prostate segmentation routine is used to segment the prostate, based on coupled appearance and anatomy models. Subsequently a voxel classification is performed using a support vector machine to compute an abnormality likelihood map of the prostate. This classification step is based on quantitative voxel features like the apparent diffusion coefficient (ADC) and pharmacokinetic parameters. Local maxima in the likelihood map are found using a local maxima detector, after which regions around the local maxima are segmented. Region features are computed to represent statistical properties of the voxel features within the regions. Region classification is performed using these features, which results in a likelihood of abnormality per region. Performance was validated using a 188 patient dataset in a leave-one-patient-out manner. Ground truth was annotated by two expert radiologists. The results were evaluated using FROC analysis. The FROC curves show that inclusion of ADC and pharmacokinetic parameter features increases the performance of an automatic detection system. In addition it shows the potential of such an automated system in aiding radiologists diagnosing prostate MR, obtaining a sensitivity of respectively 74.7% and 83.4% at 7 and 9 false positives per patient.

7963-29, Session 6

Enhanced multi-protocol analysis via intelligent supervised embedding (EMPrAvISE): detecting prostate cancer on multi-parametric MRI

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There has been increasing use of multi-parametric data for detection and staging of disease recently, leading to the development of automated quantitative meta-classifiers to analyze such data to aid in the diagnostic process. Quantitative analysis of complementary (structural, functional) multi-parametric data must account for (1) differing dimensionalities and scales of individual protocols, while (2) deriving an integrated representation of multi-parametric data which best captures all relevant information available. In this paper, we present a scheme entitled Enhanced Multi-Protocol Analysis via Intelligent Supervised Embedding (EMPrAvISE); a powerful, generalizable framework applicable to a variety of domains for multi-parametric data representation and fusion. Our scheme utilizes an ensemble of embeddings (via dimensionality reduction) which exploit the variance among multiple uncorrelated embeddings in a manner similar to ensemble classifier schemes. Relevant theoretical properties are demonstrated which show that an ensemble embedding representation will optimally preserve relevant information while best accounting for both dimensionality and scale issues in such analysis. We apply this framework to the problem of prostate cancer (CaP) detection on 12 3 Tesla in vivo multi-parametric

(T2-weighted, Dynamic Contrast Enhanced, and Diffusion-weighted) magnetic resonance imaging (MRI) datasets, comprising 39 MR images. We first align the different protocols via automated registration (accounting for differences in acquisition and resolution), followed by characterization of protocol information via quantitative image descriptors. Multiple embeddings are generated from the resultant high-dimensional feature space, which are combined intelligently to result in a single stable solution. Our scheme is employed in conjunction with graph embedding (for DR) and probabilistic boosting trees (PBTs, for robust classification) to detect CaP on multi-parametric MRI. Finally, a probabilistic pairwise Markov Random Field algorithm is used to accurately delineate lesions of CaP presence based on applying spatial constraints to the probabilistic result of the PBT classifier. Per-voxel evaluation of detection results against registered extents of CaP on MRI (from wholemount histology) show that EMPrAvISE demonstrates a statistically significant improvement (AUC=0.77) over individual protocols (AUC=0.62, 0.62, 0.65, for T2w, DCE, DWI respectively), and multi-parametric feature concatenation (AUC=0.67).

7963-30, Session 6

Empirical evaluation of bias field correction algorithms for computer-aided detection of prostate cancer on T2w MRI

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Recently, a number of automated detection algorithms for prostate cancer (CaP) using in vivo endorectal prostate magnetic resonance imagery (MRI) have been proposed. Such data is known to suffer from bias field artifacts, which are introduced by the use of an endorectal coil during acquisition. However the choice of bias field correction algorithm for prostate T2w MRI data, and the effects of correcting for bias field inhomogeneity artifacts on the efficacy of automated classification schemes have not been fully been explored. Bias field correction algorithms presented in the literature have typically been quantitatively evaluated using a generalized intensity-based measure (percent coefficient of variation, %CV). However, in the context of a specific problem (such as automated classification), the choice of bias field correction algorithm needs to be directed based on the specific objective to be optimized (such as classifier accuracy); independent of whether it simultaneously results in a reduction in %CV . In this paper, we have quantitatively compared 3 different popular bias field correction algorithms for 3 Tesla prostate T2-weighted MRI data: N3 , ITK BiasCorrector, and the method of Cohen et al. In addition to traditional evaluation measures of bias field correction (%CV), we make use of an independent application-based measure (prostate cancer detection accuracy) to evaluate the effects of these algorithms. We found that, in general, data corrected for bias field artifacts yielded a better classification accuracy compared to uncorrected data. The N3 algorithm (AUC=0.79) and the method of Cohen et al (AUC=0.79) outperformed the ITK BiasCorrector algorithm (AUC=0.65) as well as uncorrected data (AUC=0.67) in terms of classifier accuracy, despite contrasting %CV values. Based on our results, we believe that N3 may best correct prostate MRI data for the purpose of classification. Poor correlation was found between %CV and classification accuracy, suggesting the requirement for better objective measures to evaluate the efficacy of bias field correction algorithms within classification applications.

7963-31, Session 6

Automated determination of arterial input function for DCE-MRI of the prostate

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Prostate cancer is one of the commonest cancers in the world. Dynamic contrast enhanced MRI (DCE-MRI) provides an opportunity for non-invasive diagnosis, staging, and treatment monitoring. Quantitative analysis of DCEMRI relies on determination of an accurate arterial input function (AIF). Although several methods for automated AIF detection have been proposed in literature, none are optimized for use in prostate DCE-MRI, which is particularly challenging due to large spatial signal inhomogeneity. In this paper, we propose a fully automatic method for determining the AIF from prostate DCE-MRI. Our method is based on modeling pixel uptake curves as gamma variate functions (GVF). First, we analytically compute bounds on GVF parameters for more robust fitting. Next, we approximate a GVF for each pixel based on local time domain information, and eliminate the pixels with false estimated AIFs using the deduced upper and lower bounds. This makes the algorithm robust to signal inhomogeneity. After that, according to spatial information such as similarity and distance between pixels, we formulate the global AIF selection as an energy minimization problem and solve it using a message passing algorithm to further rule out the weak pixels and optimize the detected AIF. Our method is fully automatic without training or a priori setting of parameters. Experimental results on clinical data have shown that our method obtained 100% detection accuracy (all detected pixels inside major arteries), and a very good match with expert traced manual AIF. The computation time for each dataset was less than 15 seconds.

7963-32, Session 7

Classification of breast lesions in automated 3D breast ultrasound

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In this paper we investigate classification of malignant and benign lesions in automated 3D breast ultrasound (ABUS). As a new imaging modality, ABUS overcomes the drawbacks of 2D hand-held ultrasound (US) such as its operator dependence and limited capability in visualizing the breast in 3D. The classification method we present includes a 3D lesion segmentation stage based on dynamic programming, which effectively deals with limited visibility of lesion boundaries due to shadowing and speckle. A novel aspect of ABUS imaging, in which the breast is compressed by means of a dedicated membrane, is the presence of spiculation in coronal planes perpendicular to the transducer. Spiculation patterns, or architectural distortion, are characteristic for malignant lesions. Therefore, we compute a spiculation measure in coronal planes and combine this with more traditional US features related to lesion shape, margin, posterior acoustic behavior, and echo pattern. However, in our work the latter features are defined in 3D. Classification experiments were performed with a dataset of 40 lesions including 20 cancers. Linear discriminant analysis (LDA) was used in combination with leave-one-case-out and feature selection in each training cycle. We found that spiculation and margin contrast were the most discriminative features and that these features were most often chosen during feature selection. An Az value of 0.86 was obtained by merging all features, while an Az value of 0.91 was obtained by feature selection.

7963-33, Session 7

Exploring deep parametric embeddings for breast CADx

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Computer-aided diagnosis (CADx) involves training supervised classifiers using labeled ("truth-known") data. Often, training data consists of high-dimensional feature vectors extracted during analysis of the medical images. Unfortunately, a large training data set is required to produce robust classifiers when using high-dimensional inputs. To mitigate the risk of classifier over-fitting, CADx schemes may employ feature selection or dimension reduction (DR), for example, principal component analysis (PCA). Recently, a number of novel "structure-preserving" DR methods have been proposed. Such methods are an attractive option for use in CADx schemes for two main reasons. First, they can provide visualization of high-dimensional data structure, and secondly, DR may be performed in an unsupervised or semi-supervised fashion, meaning unlabeled ("truth-unknown") data may be incorporated into the algorithm. Previously, we investigated non-linear DR methods and the use of unlabeled data in the developments of CADx schemes. However, the practical application of state-of-the-art DR techniques such as, t-SNE, to CADx are inhibited by their inability to retain a parametric embedding function capable of mapping new input data. A solution to this shortcoming is to learn a parametric embedding via training of a deep (more than one hidden layer) neural network. Thus, we explored the potential feasibility of these new parametric methods for use in CADx by conducting a variety of experiments using simulated feature data. Specifically, we explored use of the unsupervised parametric t-SNE (pt-SNE) method , a supervised deep t-distributed MCML (dt-MCML) method, and a new semi-supervised modification combining the two methods.

7963-34, Session 7

The impact of motion correction on lesion characterization in DCE breast MR images

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In the context of dynamic contrast enhanced breast MR imaging we analyze the effect of motion compensation on the characterization of lesions. Two different registration techniques for motion compensation are applied: (1) rigid registration and (2) elastic registration based on the Navier-Lamé equation. It can be shown that the rate of motion outliers can be largely reduced by both rigid and elastic registration.

Voxels are interpreted as motion outliers when they exhibit a decline in image intensity after contrast injection compared to the uncontrasted native image.

It is shown that elastic registration improves the performance of lesion characterization based on imaged based features. These features include maximal signal enhancement ratio and variance of the signal enhancement ratio measured by area under the ROC curve as well as Cohen's kappa value.

7963-35, Session 7

Incorporating domain knowledge for tubule detection in breast histopathology using O'Callaghan neighborhoods

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In object detection, the identification of high-level structures is not guaranteed simply by detecting the presence of the low-level attributes that constitute the object, even in cases where these attributes might be detected in spatial proximity to each other. An important criterion for identifying complicated objects with multiple attributes is the use of domain knowledge indicating the precise spatial linking of the constituent attributes. When this domain information specifies that an object contains one attribute surrounding another, the O'Callaghan neighborhood is an ideal vehicle for linking the attributes because it allows for modeling and imposing spatial distance and directional constraints on the object attributes. In this work we apply the O'Callaghan neighborhood to the problem of tubule identification on hematoxylin and eosin stained breast cancer (BCa) histopathology, where a tubule is characterized by a central lumen surrounded by cytoplasm and a ring of nuclei. The detection of tubules is important because it plays a vital role in determining cancer grade and, consequently, patient outcome. The traditional approach to tubule detection would typically involve training classifiers to detect the lumen, cytoplasm, and nuclei individually. If these attributes are found to be spatially proximal to each other, that might suggest the presence of a tubule. However such an approach could also suffer from false positive errors due to the presence of fat, stroma, and other white areas that can be mistaken for tubules. In this paper tubules are identified by imposing spatial and distance constraints using O'Callaghan neighborhoods between the ring of nuclei around each lumen. The set of all nuclei in each image is detected via a color deconvolution scheme, which in turn is used to decompose the image into hematoxylin, eosin, and background components. Since the hematoxylin channel contains most of the nuclear information, it is binarized to provide the locations of individual nuclei. The potential lumen areas are segmented using a Hierarchical Normalized Cut algorithm that identifies white areas within the image via pixel clustering at multiple resolutions. Preliminary results show that our scheme is able to classify true lumen with 76% accuracy and 76% positive predictive value on 4500 potential lumen from 10 patients.

7963-36, Session 7

Computer-aided detection of breast masses in digital breast tomosynthesis (DBT): improvement of false positive reduction by optimization of object segmentation

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DBT is one of the promising methods that may improve the sensitivity and specificity for breast cancer detection. However, DBT could only provide quasi-3D information with limited resolution along Z direction because tomosynthesis reconstruction is an ill-posed problem. Our purpose is to develop a mass segmentation method for a CADe system in DBT. A data set of 50 two-view DBTs collected with a GE prototype system was used. We reconstructed the DBTs using a simultaneous algebraic reconstruction technique (SART). Mass candidates were identified by 3D gradient field analysis. Two-stage 3D clustering followed by active contour segmentation was applied to a volume of interest (VOI) at each candidate location. We compared a fixed-Z approach, in which the Z dimension of the VOI was pre-determined, to an adaptive-Z approach, in which Z was determined by the object diameter (D) on the X-Y plane obtained from the first-stage clustering. We studied the effect of Z ranging from D to D+8 slices, centered at the central slice, in the second stage. Features were extracted on the individual slices of the segmented 3D object and averaged over all slices for both approaches. Linear discriminant analysis with stepwise feature selection was trained with a leave-one-case-out method to differentiate true from false masses in each feature space. With proper optimization of the adaptive-Z approach, the classification accuracy was significantly improved ($p<0.0001$) in comparison with the fixed-Z approach. The improved

classifier will be useful for FP reduction in a computerized mass detection system.

7963-37, Session 8

Analysis of adipose tissue distribution using whole-body magnetic resonance imaging

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Obesity is an increasing problem in the western world and triggers diseases like cancer, type two diabetes, and cardiovascular diseases. In recent years, magnetic resonance imaging (MRI) has become a clinically viable method to measure the amount and distribution of adipose tissue (AT) in the body. However, analysis of MRI images by manual segmentation is a tedious and time-consuming process.

In this paper, we propose a semi-automatic method to quantify the amount of different AT types from whole-body MRI data. Initially, body fat is extracted by automatic thresholding. A statistical shape model of the abdomen is then used to differentiate between subcutaneous and visceral AT. Finally, fat in the bone marrow is removed using morphological operators.

The proposed method was evaluated on 15 whole-body MRI images using manual segmentation as ground truth for adipose tissue. The resulting overlap for total AT was 93.7% ± 5.5 with a volumetric difference of 7.3% ± 6.4. Furthermore, we tested the robustness of the segmentation results with regard to the initial, interactively defined position of the shape model. In conclusion, the developed method proved suitable for the analysis of AT distribution from whole-body MRI data. For large studies, a fully automatic version of the segmentation procedure is expected in the near future.

7963-38, Session 8

Computer-aided abdominal lymph node detection using contrast-enhanced CT images

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Many malignant processes cause abdominal lymphadenopathy, and computed tomography (CT) has become the primary modality for its detection. A lymph node is considered enlarged (swollen) if it is more than 1 centimeter in diameter. Which lymph nodes are swollen depends on the type of disease and the body parts involved. Identifying their locations is very important to determine the possible cause. In the current clinical workflow, the detection and diagnosis of enlarged lymph nodes is usually performed manually by examining all slices of CT images, which can be error-prone and time consuming. 3D blob detection is a usual way for computer-aided node detection. We propose a computer aided detection (CAD) system to find enlarged abdominal lymph nodes in CT images. The CAD system is designed to run on contrast-enhanced chest and abdominal CT exams obtained during a patient's evaluation. The spine is first automatically extracted to locate the abdominal region in chest and abdominal CT images. Since lymph nodes are usually next to blood vessels, abdominal blood vessels are automatically extracted and morphologically dilated as a reference to set the search region for lymph nodes. 3D blob detection is then applied to detect potential lymph nodes within the search region. Finally, the detected potential candidates are used as seeds for automatic segmentation of lymph nodes and some prior knowledge is utilized for false positive reduction. In this detection system, an improved 3D blob detection based on Hessian analysis and local object scale is proposed for potential lymph nodes detection. Since the object scale estimates the geometric information of local spherical regions, our detection does not require traditional multi-scale analysis. Another advantage is its robustness against the disturbance induced by closely located adjacent objects. We applied our detection system to 8 patients. Nine enlarged abdominal lymph nodes in these patients were manually labeled as ground truth. 8 of 9 lymph nodes were successfully detected by our system. The average false positive rate per patient was 17.

7963-39, Session 8

Novel approach for building linked statistical shape models for multimodal prostate radiotherapy planning

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We present a novel framework for building linked statistical shape models (LSSM) for automatically segmenting structures of interest in 3D MR and CT images. This framework is particularly relevant in scenarios where accurate delineations of boundary on one modality may not be readily available for training a SSM. We demonstrate this framework in the context of multi-modal prostate segmentation for radiotherapy planning. Our framework involves multi-modal registration of MRI and CT, to map 2D boundary delineations of MR training images onto their associated CT images, since MRI annotations are more readily available. Then, using the delineations from both MR and CT, 3D shapes can be constructed to build a LSSM which is used to perform segmentation on MRI and get an associated CT segmentation. This is important for prostate radiotherapy planning, where dose plans have to be formulated on CT, but accurate delineations of prostate boundary are not readily available. In order to perform segmentation using the LSSM, we employed a region-based approach that optimizes a MI-based cost criterion based on global image statistics. We acquired 8 MR-CT patient studies and used the leave-one-out strategy to train and evaluate our LSSM. We evaluated segmentation quality on both MR and CT imagery qualitatively, and quantitatively using the Dice similarity coefficient (DSC). DSC obtained on the MRI was 0.81, and on the CT it was 0.63.

7963-40, Session 8

Sampling-based ensemble segmentation against inter-operator variability

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Inconsistency and irreproducibility is commonly associated with semi-automated segmentation methods. In this study, we developed an ensemble framework to improve the reproducibility and applied to glioblastoma multiforme (GBM) brain tumor segmentation on T1-weigted contrast enhanced MR volumes. The proposed approach combines sampling-based simulations and ensemble segmentation into a single framework; it generates a set of segmentations by perturbing user initialization and user-specified internal parameters, then fused the set of segmentations into a single consensus result. Two combination algorithms were applied: averaging and expectation-maximization (EM). The reproducibility of the proposed framework was evaluated by a controlled experiment on 16 tumor cases from a multi-center drug trial. The ensemble framework had significantly better reproducibility than the individual base Otsu thresholding method ($p<.001$).

7963-41, Session 8

Toward comprehensive detection of sight threatening retinal disease using a multiscale AM-FM methodology

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Retinal pathology as a consequence of diabetics and an aging population account for 11% of visual impairment and blindness in the U.S. Two of the most common retinal diseases are Age Related Macular Degeneration (AMD) and Diabetic Retinopathy (DR). Advanced stages of DR and AMD can present with lesions not commonly addressed by other approaches to automatic screening. In this paper we present an automatic eye screening system based on multiscale Amplitude Modulation-Frequency Modulation (AM-FM) decompositions that addresses a shortcoming of current methods. Ten different experiments were performed in which abnormal features such as neovascularization, drusen, exudates, pigmentation abnormalities, and geographic atrophy (GA) are classified. The algorithm achieved an accuracy detection range of [0.77 to 0.98]area under the ROC curve for a set of 810 images.

7963-42, Session 8

Fast localization of optic disc and fovea in retinal images for eye disease screening

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Optic disc (OD) and fovea locations are the most important anatomical landmarks in automated analysis of retinal disease in color fundus photographs. This paper presents a new, fast, fully automatic optic disc and fovea localization algorithm developed for diabetic retinopathy (DR) screening. The optic disc localization methodology comprises two tasks. First, the OD location is identified using template matching and directional matched filter. The contribution of this approach is the complementary use of vessel location and orientation inside optic disc. The location of the fovea is estimated as the point of lowest matched filter response within a search area determined by the location of the optic disc. Second, optic disc segmentation is performed. Based on the detected optic disc location, a fast, hybrid level-set algorithm which combines the region information and image gradient to drive the curve evolution is used to segment the optic disc boundary. Extensive evaluation of optic disc and fovea detection is performed on 1200 images composed of 540 images of healthy retinas, 431 images with DR but no risk of Macular Edema (ME), and 229 images with DR and risk of ME. The OD location methodology obtained 98.33% success rate, while fovea location achieved 95% success rate compared to the ground truth provided by the ophthalmologists. The average computational time is 3.91seconds for optic disc and fovea location and about 5.86 seconds for optic disc boundary segmentation.

7963-65, Poster Session

Lesion classification on breast MRI through topological characterization of morphology over time

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Morphological characterization of lesions on dynamic breast MRI exams through texture analysis has typically involved the computation gray-level co-occurrence matrices (GLCM) which serve as the basis for second order statistical texture features. This study aims to characterize lesion morphology through the underlying topology and geometry with Minkowski Functionals (MF) and investigate the impact of using such texture features extracted over a dynamic time series in classifying benign and malignant lesions. 60 lesions (28 malignant & 32 benign) were identified and annotated by experienced radiologists on 54 breast MRI exams of female patients where histopathological reports were available prior to this investigation. 13 GLCM-derived texture features and 3 MF features were then extracted from lesion ROIs on all five post-contrast images. These texture features were combined into high dimensional texture feature vectors and used in a lesion classification task. A fuzzy k-nearest neighbor classifier was optimized using random sub-sampling cross-validation for each texture feature and the classification performance was calculated on an independent test set as a function of area under the ROC curve (AUC); AUC distributions of different features were compared using a Mann-Whitney U-test. The MF feature 'Area' exhibited significantly improvements in classification performance ($p<0.05$) when compared to all GLCM-derived features while the MF feature 'Perimeter' significantly outperformed 12 out of 13 GLCM features ($p<0.05$) in the lesion classification task. These results show that dynamic texture tracking of morphological characterization that relies on topological texture features can contribute to better lesion character classification.

7963-66, Poster Session

False-positive reduction using RANSAC in mammography microcalcification detection

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This paper proposes a method for false-positive reduction in mammography computer aided detection (CAD) systems by detecting a linear structure (LS) in individual microcalcification (MCC) cluster candidates, which primarily involves three steps. First, it applies a modified RANSAC algorithm to a region of interest (ROI) that encloses an MCC cluster candidate to find LS. Second, a peak-to-peak ratio of two orthogonal integral-curves (named the RANSAC feature) is computed based on the results from the first step. Last, the computed RANSAC feature is, together with other MCC cancer features, used in a neural network for MCC classification, results of which are compared with the classification without the RANSAC feature. One thousand (1000) cases were used in training the classifiers, 671 cases were used in testing. The comparison shows that there is a significant improvement in terms of the reduction of linear structure associated false-positives readings (up to about 40% FP reduction).

7963-67, Poster Session

Automatic identification of pectoral muscle on digital cranio-caudal-view mammograms

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To reduce bias errors in computerized volumetric breast density calculation, we have developed an automatic identification process which suppresses the projection of the pectoral muscle on digital CC-view mammograms. The pectoral muscle, which is of high density, but not related to risk factors, may contribute a large error in estimated breast density if counted as fibroglandular tissue. The pectoral muscle on the CC-view is more complex in appearance than that in the MLO-view as it is not always visible and has variable shape and location. The algorithm robustly detects the existence of a pectoral muscle and provides good segmentation accuracy in terms of the size and curvature of the circle segment shaped region. We present a pipeline where

adaptive thresholding and distance transforms have been used in the initial pectoral region identification process; statistical region growing is applied to explore the region at the identified location aimed at refined boundary; and a 2D shape descriptor is developed for the target validation: the segmented region is identified as the pectoral muscle if it has an ellipse-like contour. After the pectoral muscle is identified, a 1D-FFT filtering is used for boundary smoothing. A set of 173 randomly selected digital mammograms was tested on the algorithm. It has been shown to improve accuracy in our determination of volumetric ratio of breast composition by removal of the pectoral muscle from both the numerator and denominator. As well, it greatly improves the efficiency and throughput in large scale volumetric mammographic density studies.

7963-68, Poster Session

Comparison of breast percent density estimation from raw versus processed digital mammograms

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We compared breast percent density (PD%) measures from raw and post-processed digital mammographic (DM) images. Bilateral raw and processed MLO images from 80 screening studies were retrospectively collected and analyzed under HIPAA and IRB approval. Image acquisition was performed with a GE Healthcare DS full-field DM system at 0.1 mm/pixel resolution at 12 bit gray-levels. Image post-processing was performed using PremiumViewTM (GE Healthcare). Area-based breast PD% was estimated by a radiologist using a semi-automated image thresholding technique (Cumulus, Univ. Toronto). Comparison of breast PD% between raw and post-processed DM images was performed using Pearson correlation (r), linear regression, and Student's t-test. Our results show that breast PD% measurements from raw and post-processed images have a high correlation ($r=0.98$, $R2=0.95$, $p<0.001$). Paired t-test comparison of breast PD% between the raw and the corresponding post-processed images showed a statistically significant difference equal to 1.2% ($p = 0.006$). Mean PD% for our study population was 29.6% using raw and 28.4% using post-processed DM images. Our results suggest that, although statistically significant, the relatively small magnitude of the observed absolute difference in PD% between raw and post-processed DM images is unlikely to be clinically significant in breast cancer risk stratification. Therefore, post-processed DM images could be viable for breast PD% estimation in clinical settings. Since most breast imaging clinics routinely use and store only the post-processed DM images, breast PD% estimation from post-processed DM data may accelerate the integration of breast density in breast cancer risk assessment models used in clinical practice.

7963-69, Poster Session

Automatic lesion detection and segmentation algorithm on 2D breast ultrasound images

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Although X-ray mammography (MG) is the dominant imaging modality, ultrasonography (US), with recent advances in technologies, has proven very useful in the evaluation of breast abnormalities. But radiologist should investigate a lot of images for proper diagnosis unlike MG. This paper proposes the automatic algorithm of detecting and segmenting lesions on 2D breast ultrasound images to help radiologist. The detecting part is based on the Hough transform with downsampling process which is very efficient to sharpen the smooth lesion boundary and also to reduce the noise. In segmenting part, radial dependent contrast adjustment (RDCA) method is newly proposed. RDCA is introduced to overcome the limitation of Gaussian constraint function. It decreases contrast around the center of lesion but increases contrast proportional to the distance from the center of lesion. As a result, segmentation algorithm shows robustness in various shapes of lesion. The proposed algorithms may help to detect lesions and to find boundary of lesions efficiently.

7963-70, Poster Session

Multi-probe-based resonance-frequency electric impedance spectroscopy for detection of suspicious breast lesions: improving performance using partial ROC optimization

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We have developed a multi-probe resonance-frequency electrical impedance spectroscope (REIS) system to detect breast abnormalities. Based on assessing asymmetrical level of REIS signals acquired between left and right breasts, we developed several machine learning classifiers to classify younger women (i.e. under 50YO) into two groups of having high and low risk for developing breast cancer. In this study, we investigated a new method based on the area under a selected partial receiver operating characteristic (ROC) curve to optimize an artificial neural network (ANN), and tested whether it could achieve improved classification performance. From an ongoing prospective study, we selected a dataset of 174 cases with both REIS examinations and diagnostic verification. The dataset includes 66 "positive" cases recommended for biopsy due to detection of highly suspicious breast lesions and 108 "negative" cases determined in mammography. A set of REIS-based feature differences, extracted using a mirror-matched manner from two breasts, was computed to generate an initial feature pool. Using a leave-one-case-out cross-validation method, we applied a genetic algorithm (GA) to train the ANN with an optimal subset of features. Two optimization criteria were separately used in GA optimization, namely an area under the entire ROC curve (AUC) and an area under the partial ROC region (i.e., $\geq$90% specificity). The results showed that although the ANN optimized using the overall AUC yielded higher testing AUC (0.83 versus 0.76), the ANN optimized using the partial ROC area criterion achieved substantially higher operation performance (i.e. increasing the sensitivity level from 28% to 48% at 95% specificity or from 48% to 58% at 90% specificity).

7963-71, Poster Session

Study of adaptability of breast density analysis system developed for screen film mammograms (SFMs) to full-field digital mammograms (FFDMs): robustness of parenchymal texture analysis

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Mammography is in the transition to FFDM. It is important to evaluate the adaptability of image analysis methods and CAD systems developed with digitized film mammograms (SFMs) to FFDMs. In addition, prior SFMs are more readily available for development of new techniques that involve long-term follow up such as breast cancer risk prediction. This study investigated the adaptability of a mammographic parenchymal pattern (MPP) analysis system that we developed with SFMs for breast cancer risk prediction to FFDM. A data set of SFM and FFDM of the same breast was collected from 182 subjects with informed consent. The time interval between the SFM and the corresponding FFDM was 0-59 days. Our MPP analysis algorithm consisted of 3 steps: (1) breast boundary detection, (2) texture feature extraction (1 spatial gray level dependence (SGLD) feature, 2 gray level difference statistics (GLDS) features, and 2 run-length statistics (RLS) features), and (3) generation of MPP measure with linear discriminant analysis. Pearson's correlation coefficient was

used to analyze the association of individual features as well as the MPP measures between matched pairs of SFM and FFDM. It was found that the correlation coefficients between the individual texture features ranged from 0.71 to 0.93. The SGLD feature had the highest whereas one of the RLS features had the lowest correlation. The correlation coefficient of the MPP measures was 0.87 (two tailed $P < 0.05$). This result indicated that the SFM-trained MPP analysis system for breast cancer risk prediction can be adapted to FFDMs with at most minor retraining.

7963-72, Poster Session

Computer aided breast density evaluation in cone beam breast CT

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Cone Beam Breast CT (CBBCT) is a three-dimensional breast imaging modality with high soft tissue contrast, high spatial resolution and no tissue overlap. With these advantages, it is possible to measure breast density accurately and quantitatively with CBBCT 3D images. In this research, a modified morphological processing is applied to the CBBCT images to detect the skin of the breast. After the skin is removed, a stepwise fuzzy clustering algorithm is applied to the CBBCT image volume to adaptively cluster the image voxels. Finally, the CBBCT breast volume is divided into three categories: skin, fat and glands. Phantom study is designed to evaluate the accuracy of the scheme. Clinical study is designed and the quantitative CBBCT breast density evaluation results are compared with the mammogram-based BIRADS breast density categories.

7963-73, Poster Session

Minimal elastographic modeling of breast cancer for model based tumour detection in a digital image elasto tomography (DIET) system

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Digital Image Elasto Tomography (DIET) is a non-invasive breast cancer screening technology that images the surface motion of a breast under harmonic mechanical actuation. A new approach capturing the dynamics and characteristics of tumour behaviour is presented. A simple mechanical model of the breast is used to identify a transfer function relating the input harmonic actuation to the output surface displacements using imaging data of a silicone phantom. Areas of higher stiffness cause significant changes of damping and resonant frequencies as seen in the resulting Bode plots. A case study on a healthy and tumour silicone breast phantom shows the potential for this model-based method to clearly distinguish cancerous and healthy tissue as well as correctly predicting the tumour position.

7963-74, Poster Session

A prototype of mammography CADx scheme integrated to imaging quality evaluation techniques

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As all women over the age of 40 are recommended to perform mammographic exams every two years, the demands on radiologists to evaluate mammographic images in short periods of time has increased considerably. As a tool to improve quality and accelerate analysis CADe/Dx (computer-aided detection/diagnostic) systems are being researched, but very few complete CADe/Dx schemes have been developed and most are restricted to detection and not diagnosis. The existent ones usually are associated to specific mammographic equipments (usually DR), which makes them very expensive.

This paper describes a prototype of a complete mammography CADx scheme developed by our research group integrated to an imaging quality evaluation process. Its basic structure consists of pre-processing stages based on the image acquisition and digitization procedures (FFDM, CR or film + scanner), a segmentation tool to detect clustered microcalcifications and suspect masses and a classification scheme, which evaluates as the presence of microcalcifications clusters as well as possible malignant masses based on their contour. The aim is to provide enough information not only on the detected structures but also a pre-report with a BI-RADS classification.

At this time the system is still lacking an interface integrating all the modules. Despite this, it is functional as a prototype for clinical practice testing, with results comparable to others reported in literature.

Future developments includes the complete integration of the system using a single user-friendly interface using JAVA®, and integration of the system with our online image database (“BancoWeb”) for comparison of results.

7963-75, Poster Session

Classification of mammographic masses: use and influence of a bilateral-filter-based flat-texture approach

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Computer-assisted diagnosis (CADx) for the characterization of mammographic masses as benign or malignant has a high potential to help radiologists during the critical process of diagnostic decision making. By default, the characterization of mammographic masses is performed by extracting features from a region of interest (ROI) depicting the mass.

To investigate the influence of a bilateral filter-based flat-texture preprocessing step on the classification performance, textural as well as frequency-based features are calculated in the ROI (which has been manually delineated by an expert), in the core of the mass and in the mass margin for preprocessed and unprocessed images. Classification is done using a k-NN classifier. The classification performance was evaluated using the area Az under the receiver operating characteristic curve.

A publicly available mammography database was used as data set. The comparison of the results showed that the proposed preprocessing step has a positive influence on the texture-based feature extractors and that frequency-based feature extractors perform better on the unprocessed images.

7963-76, Poster Session

Comparison of two-class and three-class Bayesian artificial neural networks in estimation of observations drawn from simulated bivariate normal distributions

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The development and application of multi-class BANN classifiers in computer-aided diagnosis methods motivated this study in which we compared estimates produced by two-class and three-class BANN classifiers to true observations drawn from simulated distributions. Observations were drawn from three Gaussian bivariate distributions

with distinct means and variances to generate G1, G2, and G3 simulated datasets. A two-class BANN was trained on each training dataset for a total of ten different trained BANNs. The same testing dataset was run on each trained BANN. The average and standard deviation of the resulting ten sets of BANN outputs were then calculated. This process was repeated with three-class BANN. Different sample numbers and values of a priori probabilities were investigated. The relationship between the average BANN output and true distribution was measured using Pearson and Spearman coefficients, R-squared and mean square error for two-class and three-class BANNs. There was significantly high correlation between the average BANN output and true distribution for two-class and three-class BANNs; however, subtle non-linearities and spread were found in comparing the true and estimated distributions. The standard deviations of two-class and three-class BANNs were comparable, demonstrating that three-class BANNs can perform as reliably as two-class BANN classifiers in estimating true distributions and that the observed non-linearities and spread were not simply due to statistical uncertainty but were valid characteristics of the BANN classifiers. In summary, three-class BANN decision variables were similar in performance to those of two-class BANNs in estimating true observations drawn from simulated bivariate normal distributions.

7963-77, Poster Session

A preparatory study to choose similarity metrics for left-ventricle segmentations comparison

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Medical image processing and analysis has become a major research topic in different application areas. One important task performed over medical images is segmentation, which is often necessary to allow quantitative measures of extent, volume and shape.

A major concern when performing image segmentation (automatic or manual) is to account for its accuracy and variability: how close is it to the 'real' anatomic region? how much does it differ when performed by different users? and how much does it differ when performed by the same user (or automatic method) at different times?

Evaluation studies are used to assess these questions by gathering segmentations and comparing them among themselves or with a ground truth using several similarity metrics.

For particular situations some of the metrics might not be 'sensible' to the typically expected differences or several of them might just provide equivalent results. Using the largest number of metrics might seem the easiest option but it has considerable implications if a large number of volumes must be compared. Therefore, a preliminary study should be performed to assess the behavior of the different metrics and decide which ones are relevant to use.

In this article we start by providing a short overview on several similarity measures described in the literature. Then, several of those measures are used to compute the differences between volumes obtained using a left ventricle segmentation tool. A statistical analysis involving exploratory data analysis and multivariate techniques follows which characterizes the behavior of each metric, highlighting similarities among them. Finally, some conclusions are presented.

7963-78, Poster Session

Robust detection of bifurcations for vessel tree tracking

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Vessel tree tracking is an important and challenging task for many medical applications. This paper presents a novel bifurcation detection algorithm for Bayesian tracking of vessel trees. Based on a cylindrical model, we introduce a bifurcation metric that yields minimal values at potential branching points. This approach avoids searching for bifurcations in every iteration of the tracking process (as proposed by prior works) and is therefore computationally more efficient. We use the same geometric model for the bifurcation metric as for the tracking; no specific bifurcation model is needed. In a preliminary evaluation of our method on 8 CTA datasets of coronary arteries, all main branches and 75% of all side branches were detected correctly.

7963-79, Poster Session

Optical coherence tomography layer thickness characterization of a mock artery during angioplasty balloon deployment

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In this paper, we use an optical coherence tomography (OCT) probe which is inserted in a balloon catheter to monitor balloon inflation inside a mock artery. This setup can be very beneficial to study in real-time the tissue deformation due to balloon deployment. As an example, characterization of thickness of different layers in an artery phantom is presented. Swept-source OCT is used for imaging. A 4 mm semi-compliant polyurethane balloon was built for experiments. The balloon is inflated inside a custom-built artery phantom. The inflation pressure increases from 0 to 4 atm. The phantom has three layers to mock artery layers, namely, intima, media and adventitia. Segmentation of phantom layers is performed to provide a detailed assessment of luminal diameter and layer thickness at various deployment pressures. The segmentation algorithm is semi-automatic for images acquired at lower pressures (e.g. 0 and 1 atm) where the balloon folding distorts the image. The algorithm is automatic for images acquired at higher pressures (e.g. 2, 3 and 4 atm). The results indicate that during the course of balloon deployment the estimated luminal diameter increases from 3.4 mm to 4.8 mm. The estimated thicknesses of the mock media, the mock adventitia and the phantom decrease by 30 %, 20 %, and 27 %, respectively. This demonstrates that similar measurements are possible in a real artery to provide a detailed monitoring of the effect of balloon inflation.

7963-80, Poster Session

Plaque characterization in ex vivo MRI evaluated by dense 3D correspondence with histology

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Automatic quantification of carotid artery plaque composition is important in the development of methods that distinguish vulnerable from stable plaques. MRI has shown to be capable of imaging different components non-invasively. We present a new plaque classification method which uses 3D registration of histology data with ex vivo MRI data, using non-rigid registration, both for training and evaluation. This is more objective than previously presented methods, as it eliminates selection bias that is introduced when 2D MRI slices are manually matched to histological slices before evaluation.

Histological slices of human atherosclerotic plaques were manually segmented into necrotic core, fibrous tissue and calcification. Classification of these three components was voxelwise evaluated. As

features the intensity, gradient and Laplacian in four MRI sequences after different degrees of Gaussian smoothing, and the distances to the lumen and the outer vessel wall, were used. Performance of linear and quadratic discriminant classifiers for different combinations of features was evaluated. Best accuracy (72.5 ± 7.7%) was reached with the linear classifier when all features were used. Although this was only a minor improvement to the accuracy of a classifier that only included the intensities and distance features (71.6 ± 7.9%), the difference was statistically significant (paired t-test, $p<0.05$). Good sensitivity and specificity for calcification was reached (83% and 95% respectively), however, differentiation between fibrous (sensitivity 85%, specificity 60%) and necrotic tissue (sensitivity 49%, specificity 89%) was more difficult.

7963-81, Poster Session

Estimation of myocardial volume at risk from CT angiography

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The determination of myocardial volume at risk distal to coronary stenoses provides important information for prognosis and treatment of coronary artery disease. In this paper, we present a novel computational framework for estimating the myocardial volume at risk in computed tomography angiography (CTA) imagery. Initially, epicardial surface, endocardial surface, and coronary arteries are extracted using an active contour method. Then, the extracted coronary arteries are represented by their centerlines and projected onto the epicardial surface, and each point on this surface is associated with its closest coronary artery using Geodesic distance measurement. The likely myocardial region at risk on epicardial surface caused by a stenosis is approximated by the region with all its inner points associated with the sub-branches distal to the stensis in the coronary artery tree. Finally, the likely myocardial volume at risk is approximated by the volume in between the region at risk on the epicardial surface and its projection on the endocardial surface, which is expected to yield computational savings over risk volume estimation using the entire image volume. Initial experiments demonstrate the effectiveness of the proposed approach.

7963-82, Poster Session

Developments of thrombosis detection algorithm using the contrast enhanced CT images

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In the diagnosis of thrombosis with no specific clinic symptoms, diagnostic imaging plays a greater role. Particularly, contrast Enhanced CT is low invasive diagnostics, and the thrombus in the pulmonary artery can be detected as a low density without the contrast effect. Moreover, because describing the change of concentration in lung field and the decline in lung blood vessel shadow is also possible, it is indispensable to diagnose thrombosis. As the image diagnosis support, it is necessary to classify the pulmonary artery and vein that relate to the thrombosis, and to analyze the lung blood vessel quantitatively. In this study, the effectiveness of the method is shown by analyzing the structure by using the extracted pulmonary artery through semi-automated method, measuring the pulmonary trunk diameter, and comparing it with a normal case.

7963-83, Poster Session

Multimodal medical image retrieval

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Medical image retrieval systems, whose goal is to find the most relevant medical image information in response to medical queries, can play a vital role in medical diagnosis, research, and education. While traditional medical retrieval systems rely mainly on textual information or patient identifications, this paper focuses on the problem of content-based medical image retrieval using multi-modal information. Specifically, we propose a generative model-based approach for medical image retrieval using both visual and textual information. This approach is based on a new unsupervised learning method using an extended probabilistic Latent Semantic Analysis (pLSA) model.

There are two components in our proposed system. The first one is the “Training Component” and the second is the “Retrieval Component”. The goal of the “Training Component” is to build the model and generate the latent topic representation for each image in the database. The input of this component includes the images and their textual descriptions. Our algorithms will generate a latent topic representation for each image. For the “Retrieval Component”, our method takes a query image as input and generates the latent topic representation for this image. Finally, we compare the distance between the images in the database and the query image by performing a histogram intersection between the latent topic representations. The images in the database are ranked based on the similarity score.

To show the effectiveness of our approach, we use the medical images from the ImageCLEF 2009 medical retrieval challenge, which is a widely used dataset for medical image retrieval. The overall performance is encouraging with a Mean Average Precision (MAP) at 0.29. Compared with the existing work, our algorithm is ranked as one of the top performers.

7963-84, Poster Session

Liver tumor detection and classification using content-based image retrieval

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Computer aided liver tumor detection and diagnosis may be invaluable in assisting radiologists interpret abnormal features in liver CT scans. In this paper, a general frame work is proposed to detect and enable differential diagnosis of liver tumors. The algorithm first segments whole liver from the CT data using a model-based method and in the second step detects abnormalities from the liver using contrast enhancement and hessian filtering based methods. It ranks these abnormalities with respect to symmetry, compactness and size using a fuzzy inference to facilitate fast location of regions of interest. To differentiate liver tumors, content-based image retrieval (CBIR) is employed to query an image database of tumor sample models. It extracts local shape and texture features from both query image and models and integrates these features into hypercube indexing structures. Image query is implemented by the indexing structure intersection. The similarity score is calculated to rank the retrieval results. The most similar sample indicates the tumor’s type and the normalized similarity score gives the accuracy of the classification. The proposed framework is general since it detects tumors using a subtraction, i.e. normal tissue/organ subtraction, thus, avoid definition of special tumors. In addition, it recognizes tumors using a similarity query, which can potentially generalize the proposed to any tumor recognition if the sample modals of the tumor are available in the database. Moreover, the proposed framework is applicable to other image modalities such as MRI and ultrasound. Initial results obtained from four CT datasets are

promising and provide motivation for refining the methods and results. The database will be increased to include more data sets in the near future.

7963-85, Poster Session

3D lung image retrieval using localized features

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The interpretation of high-resolution computed tomography (HRCT) images of the chest showing disorders of the lung tissue associated with interstitial lung diseases (ILDs) is time-consuming and requires experience. Whereas automatic detection and quantification of the lung tissue patterns showed promising results in several studies, its aid for the clinicians is limited to the challenge of image interpretation, letting the radiologists down with the problem of the final histological diagnosis. Complementarily to lung tissue categorization, providing visually similar cases using content-based image retrieval (CBIR) is in accordance with the clinical workflow of the radiologists.

In a preliminary study, we used an Euclidean distance based on the percentages of volumes of five lung tissue types as inter-case distance for CBIR. The latter showed good results although no localization information was used for CBIR. However, to retrieve and show similar images with pathology, appearing at a particular lung position was not possible. In this work, a 3D localization system based on lung anatomy is utilized to localize low-level features used for CBIR.

When compared to our previous study, the introduction of localization features allowed to improve retrieval precision for some histological diagnoses, especially when the region of appearance of lung tissue disorders is important. It also worth noting that the link between visual similarity of two HRCT scans and their associated diagnoses is not straightforward. Finally, a system showing cases that are visually similar but with distinct diagnoses prevents the reader from mixing diagnoses with similar radiological findings.

7963-86, Poster Session

Similarity evaluation between query and retrieved masses using a content-based image retrieval (CBIR) CADx system for characterization of breast masses on ultrasound images: an observer study

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The purpose of this study is to evaluate the similarity between the query and retrieved masses by a Content-Based Image Retrieval (CBIR) CADx system for characterization of breast masses on ultrasound (US) images based on radiologists' visual similarity assessment. We designed a CADx system to assist radiologists in characterizing masses on US images. The CADx system retrieves masses that are similar to a query mass from a reference library based on automatically extracted image features. An observer study was performed to compare the retrieval performance of four similarity measures: Euclidean distance (ED), Cosine (Cos), Linear Discriminant Analysis (LDA), and Bayesian Neural Network (BNN). For ED and Cos, a k-nearest neighbor (k-NN) algorithm was used for retrieval. For LDA and BNN, the features of a query mass were combined first into a malignancy score and then masses with similar scores were retrieved. For a query mass, three most similar masses were retrieved with each method and were presented to the radiologists in random order. Three MQSA radiologists rated the similarity between the query mass and the computer-retrieved masses using a nine-point similarity scale (1=very dissimilar, 9=very similar). The average similarity ratings of all radiologists for LDA, BNN, Cos, and ED were 4.71, 4.77, 5.18 and 5.32. The ED and Cos measures retrieved masses of significantly higher similarity ($p<0.002$) than LDA and BNN. Although the BNN measure had the best classification performance (Az: 0.86±0.03) in the CBIR scheme and ED had the worst performance (Az: 0.80±0.03), ED exhibited higher image retrieval performance than others based on radiologists' assessment.

7963-87, Poster Session

Automatic colonic polyp shape determination using content-based image retrieval

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Polyp shape (sessile or pedunculated) may provide important clinical implication. However, the traditional way of determining polyp shape is both invasive and subjective. We present a less-invasive and automated method to predict the shape of colonic polyps at computed tomographic colonography (CTC) using the content-based image retrieval (CBIR) approach. We classify polyps as either sessile (SS) or pedunculated (PS) in shape. The CBIR uses numerical feature vectors generated from our CTC computer aided detection (CTC-CAD) system to describe the polyps. These features relate to physical and visual characteristics of the polyp. Feature selection was done using a support vector machine classifier on a training set of polyp shapes, leaving four features. The system is evaluated using an independent test set. Using receiver operating curve (ROC) analysis, we showed our system is accurate as a polyp shape classifier. The area under the ROC curve was 0.86 (95% confidence interval [0.77, 0.93]).

7963-88, Poster Session

BI-RADS guided mammographic mass retrieval

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In this study, a mammographic mass retrieval platform was developed and validated. This system was established using content-based image retrieval (CBIR) method to extract and to model the semantic content of mammographic masses. Specifically, the shape and margin of a mass was classified into different categories, which were sorted by radiologist experts according to BI-RADS descriptors. Mass lesions were analyzed by the likelihoods of each category with defined features including third order moments, curvature scale space descriptors, compactness, solidity, and eccentricity, etc. To evaluate the performance of the CBIR system, we defined that a retrieved image is considered relevant if it belongs to the same class (benign or malignant) as the query image. A total of biopsy-proven 476 mass samples were used for 10 random test/train partitions. For each run, a test set of 76 masses (38 malignant and 38 benign) were randomly drawn from the data set. The retrieval system was reset and retrained using the remaining 400 samples which served as reference library for retrieval. For each test query mass, 5 similar masses were retrieved from the system. The malignancy rating of the query mass was estimated as the fraction of retrieved masses being malignant. The performance of the retrieval system was evaluated by ROC analysis of the malignancy rating of the query masses in the test set relative to the biopsy truth. Through 10 random test/train partitions, we found that the averaged area under the ROC curve (Az) was 0.80 +- 0.056.

7963-89, Poster Session

A context-aware approach to content-based image retrieval of lung nodules

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We are investigating various techniques to improve the quality of Content-Based Image Retrieval (CBIR) for computed-tomography (CT) scans of lung nodules. Previous works have used linear regression models and artificial neural networks (ANN) to predict the similarity between two nodules. This paper expands upon this work incorporating contextual information utilizing the Rubber Band Straightening Transformation applied to the boundaries around lung nodules to determine if the existing model using an ANN will produce a better correlation between content-based and semantic-based human perceived similarity. We observed that our ANN using contextual information showed a statistically significant increase in the correlation coefficient of between predicted nodule similarity and similarity derived from the Jeffrey Divergence.

7963-90, Poster Session

Computer-aided detection of small bowel strictures in CT enterography

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Computer-aided detection (CAD) of small bowel strictures can have significant impact in improving the workflow of CT enterography in an emergency setting where even inexperienced radiologist could use it to rapidly detect sites of obstruction. A CAD scheme was developed to detect strictures from abdominal CT enterography data by use of template matching and blob detection. A pilot observer study was performed with 15 patients including 22 surgically confirmed strictures. The CAD scheme detected 77% of strictures with an average of 5 false positives per patient. Despite the relatively low sensitivity of CAD, the sensitivity of the radiologist aided by CAD was comparable with that of unaided radiologist (unaided radiologist: 81%; aided radiologist: 77%; $p=0.07$), whereas the time taken to identify strictures was significantly less when the radiologist was aided by CAD ($p<0.0001$). Most of the false-positive CAD detections were caused by collapsed bowel loops, approximated bowel wall, muscles or vessels, and they were easy to dismiss. The preliminary results indicate that CAD may provide radiologists with rapid and accurate interpretations of strictures to improve the workflow in an emergency setting.

7963-91, Poster Session

Detection of metastatic liver tumor in multiphase CT images by using a spherical gray-level differentiation searching filter

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Malignant liver tumor causes 1.25 million deaths per year worldwide and Multidetector CT (MDCT) is currently an effective diagnostic modality for the detection, characterization of liver tumors. To aid the radiologists' interpretation of large number of images, we develop a computer aided diagnosis (CAD) system for the detection of metastatic liver tumor on CT scans. Two liver edge maps on unenhanced and portal venous phase images are firstly extracted and registered using phase-only correlation (POC) method, by which rotation and shift parameters are detected on two power spectrum images and two special images, respectively. Then the liver gray map is obtained on portal vein phase images from calculating the gray value within the region of edge map. The initial tumors are derived from the subtraction of edge and gray maps as well as the score from spherical gray-level differentiation searching (SGDS) filter. Finally the FPs are eliminated by shape and texture features. 12 normal cases and 25 cases with 44 metastatic liver tumors are used to test the performance of our algorithm, 86.7% of TPs are successfully extracted by our CAD system with 2.5 FPs per case. The result demonstrates that the POC is a robust method for the liver registration, and our proposed (SGDS) filter is effective to detect spherical shape tumor on CT images. It is expected that our CAD system could useful in clinical practice.

7963-92, Poster Session

Automatic colonic lesion detection and tracking in endoscopic videos

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The biology of colorectal cancer offers an opportunity for both early detection and prevention. Compared with other imaging modalities, optical colonoscopy is the procedure of choice for simultaneous detection and removal of colonic polyps. In current colonoscopy practices, "image processing "by the human brain plays the dominant role with operator experiences and imaging quality influencing the ability of recognize diagnostic features and patterns. Computer assisted screening makes it possible to assist the physicians and potentially improve the accuracy of the diagnostic decision during the exam. This paper presents an unsupervised colonic lesion detection and tracking scheme guided by the salience structure of the colon. The aim of the lesion screening and tracking is to facilitate detection of polyps and abnormal mucosa in real time as the physician is performing the procedure. For colonic lesion detection, the conventional marker controlled watershed based segmentation is used to segment the colonic lesions, followed by an adaptive ellipse fitting strategies to further validate the shape. Texture parameter extracted for mathematical morphology and a salience map based on the edge information are also extracted to help identify the polyp shape. For lesion tracking, a mean shift tracker with background modeling is used to track the target region from the detection phase. Different methods of target modeling are implemented and the performance is evaluated against the template matching method. The approach has been tested with both white light and narrow band imaging colonoscopy video and showed promising results.

7963-93, Poster Session

Active contours for localizing polyps in colonoscopic NBI image data

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Colon cancer is the third most common type of cancer in the United States of America. Every year about 140,000 people are newly diagnosed with colon cancer. Early detection is crucial for a successful therapy. The standard screening procedure is colonoscopy. During this endoscopic examination physicians can locate colon polyps and remove them if necessary. For example, adenomatous colon polyps are deemed to be a preliminary stage of colon cancer. However, the removal of a polyp can lead to complications like severe bleedings or colon perforation. Thus, only polyps diagnosed as potentially malignant should be removed. Vascular patterns were shown to be a reliable indicator for the decision whether a polyp is potentially malignant. Narrow-Band imaging (NBI) is a new tool to improve visibility of vascular patterns on polyp surfaces. Localization of polyps is the first step towards an automated polyp classification system. We propose Active Contours for the localization of colon polyps in NBI image data. Though often elliptic, the shape of polyps is highly variable. Active Contours offer the flexibility to adapt to polyp shapes well. Furthermore, to avoid clustering of contour polygon points we propose the application of Active Rays. The quality of the results was evaluated based on manually localized polyps as ground truth data. The results were compared to a template matching approach and to the generalized Hough transform.

7963-94, Poster Session

Automatic teniae coli detection for computed tomography colonography

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Human colon has complex structures since it turns, twists, and even mobiles when the position of patient changes. The awareness of the locations and orientations is very important for improving the experience of virtual navigation, registration of supine/prone images and polyp matching. Teniae coli (TCs) are three longitudinal muscles along the human colon. They are parts of the colon wall, and they have the potential to serve as reliable landmarks to provide the above mentioned awareness. Morphologically, TCs are three smooth narrow bands, approximately perpendicular to the haustral folds, and extending between the fold pairs in a parallel manner. Such characteristics make the TCs detectable if the folds have been extracted already. In this study, based on the previous work of the segmentation of haustral folds, we introduce a new method of automatically detecting the three TCs. The experiments will be conducted on real patient studies to demonstrate the feasibility of the method.

7963-95, Poster Session

Quantitative CT imaging for adipose tissue analysis in mouse model of obesity

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In obese humans CT imaging is a validated method for follow up studies of adipose tissue distribution and quantification of visceral and subcutaneous fat. Equivalent methods in murine models of obesity are still lacking. Current small animal micro-CT involves long-term X-ray exposure precluding longitudinal studies. We have overcome this limitation by using a human medical CT which allows very fast 3D imaging (2 sec) and minimal radiation exposure. This work presents novel methods fitted to in vivo investigations of mice model of obesity, allowing (i) automated detection of adipose tissue in abdominal regions of interest, (ii) quantification of visceral and subcutaneous fat.

For each mouse, 1000 slices (100µm thickness, 160 µm resolution) were acquired in 2 sec using a Toshiba medical CT (135 kV, 400mAs). A Gaussian mixture model of the Hounsfield curve of 2D slices was computed with the Expectation Maximization algorithm. Identification of each Gaussian part allowed the automatic classification of adipose tissue voxels. The abdominal region of interest (umbilical) was automatically detected as the slice showing the highest ratio of the Gaussian proportion between adipose and lean tissues. Segmentation of visceral and subcutaneous fat compartments was achieved with 2D ½ level set methods.

Our results show that the application of human clinical CT to mice is a promising approach for the study of obesity, allowing valuable comparison between species using the same imaging materials and software analysis.

7963-96, Poster Session

Colonoscopy video quality assessment using hidden Markov random fields

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With colonoscopy becoming a common procedure for individuals aged 50 or more who are at risk of developing colorectal cancer (CRC), colon video data is being accumulated at an ever increasing rate. However, the clinically valuable information contained in these videos is not being maximally exploited to improve patient care and accelerate the development of new screening methods. One of the well-known difficulties in colonoscopy video analysis is an abundance of frames with no diagnostic information. Approximately 40% - 50% of the frames in a colonoscopy video are deteriorated by noise, acquisition errors, glare, blur, and uneven illumination. Therefore, filtering out low quality frames containing no diagnostic information will significantly improve the efficiency of colonoscopy video analysis. To address this challenge, we present a quality assessment algorithm to detect and remove such uninformative frames. The goal of our algorithm is to retain informative frames with diagnostic relevance, and discard uninformative, low quality frames. The algorithm is developed based on a hidden Markov model (HMM) in combination with two measures of data quality to filter out uninformative frames. Furthermore, we present a high-level framework based on an embedded hidden Markov model (EHHM) to incorporate the proposed quality assessment algorithm into further automated diagnostic image analysis on colonoscopy video.

7963-97, Poster Session

Development of automated quantification of visceral and subcutaneous adipose tissue volumes from abdominal CT scans

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This contribution describes a novel algorithm for the automated quantification of visceral and subcutaneous adipose tissue volumes from abdominal CT scans of colorectal resection patients. Visceral and subcutaneous adipose tissue volumes can accurately be measured with errors of 1.2 and 0.5 %, respectively. Also the reproducibility of CT measurements is good; a disadvantage is the amount of radiation. In this study no high resolution is necessary, so a low dose protocol can be applied. However the standard work-up of (colorectal) cancer includes a CT, the data of that study can be used, thus there is no additional radiation. Obesity is a well known risk factor for complications in and after surgery. Body Mass Index (BMI) is a widely accepted indicator of obesity, but it is not specific enough for risk assessment of colorectal surgery. We report on an automated method to quantify visceral and subcutaneous adipose tissue volumes as a basic step in a clinical research project concerning pre-operative risk assessment. The outcomes are to be correlated with the surgery results. The hypothesis is that the balance between visceral and subcutaneous adipose tissue together with the presence of calcifications in the major bloodvessels, is a predictive indicator for complications such as anastomotic leak to be expected in colorectal surgery. We start with four different computer simulated humanoid abdominal volumes with tissue values in the appropriate Hounsfield range at different dose levels. With satisfactory numerical results for this test, we have applied the algorithm on over a 100 patient scans and have compared results with manual segmentations by an expert. The results are within a 5% difference. Compared to other studies reported in the literature, reliable values are obtained for visceral and subcutaneous adipose tissue areas.

7963-98, Poster Session

Automated contralateral subtraction of dental panoramic radiographs for detecting abnormalities in paranasal sinus

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Inflammation in paranasal sinus is often observed in pollinosis or cold, but some of them are carcinoma of maxillary sinus or maxillary cyst. The detection of those findings in dental panoramic radiographs is not difficult to detect for radiologists, however general dentists may miss the findings because they focus on treatments of teeth. The purpose of this work is to develop a contralateral subtraction method for detecting odontogenic sinusitis region on dental panoramic radiographs.

7963-99, Poster Session

Robust feature selection from DESI MS Imaging for biomarker identification in brain gliomas

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We propose to extend previous research on the classification of glioma subtypes from mass spectrometry (MS) data by exploring novel feature selection techniques. Feature selection is an essential first step in classification, as the dimensionality of the original mass spectrometry data is very high, and dimensionality reduction is necessary to reduce computation time and increase the robustness of the classification framework. More importantly, feature selection from mass spectrometry data is useful towards identifying biomarkers that are significant in gliomas. The data in this work is obtained from Desorption Electrospray Ionization MS (DESI MS), a novel mass spectrometry acquisition technique that eliminates the need for sample preparation and thus enables the intraoperative use of the modality. We use support vector machines (SVM) for classification and explore two methods of reducing the feature set. One method selects features with maximal disparity using metrics (both parametric and nonparametric) like the Kolmogorov-Smirnov statistics, the Student's t-statistics, and the Bhattacharyya distance. The other method is the Maximum Influence Feature Selection (MIFS), an iterative method that chooses the ideal set of features that maximizes the distance between the two classes. This work compares the different metrics and objective functions that give highest accuracy in classification, and compares the different feature selection methods in-depth towards understanding their impact on classification performance, as well as understanding the identified features as potential biomarkers (via the tandem MS technique), and exploring optimal combinations of these methods towards the goal of biomarker detection.

7963-100, Poster Session

Preoperative volume determination for pituitary adenoma

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The most common sellar lesion is the pituitary adenoma, and sellar tumors are approximately 10-15% of all intracranial neoplasms. Manual slice-by-slice segmentation takes quite some time that can be reduced by using appropriate algorithms. In this contribution, we present a segmentation method for pituitary adenoma. The method is based on an algorithm that we have applied recently to segmenting glioblastoma multiforme. A modification of this scheme is used for adenoma segmentation that is much harder to perform, due to lack of contrast-enhanced boundaries. In our experimental evaluation, neurosurgeons performed manual slice-by-slice segmentation of ten magnetic resonance imaging (MRI) cases. The segmentations were compared to the segmentation results of the proposed method using the DSC. The average DSC for all datasets was 76%. A manual segmentation takes about four minutes, while our algorithm required about one second.

7963-101, Poster Session

Prediction of brain tumor progression using multiple histogram matched MRI scans

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In a recent study, we investigated the feasibility of predicting brain tumor progression based on multiple MRI series and we tested our methods on two patients' MRI images scanned at three consecutive visits A, B and C. Experimental results showed that it is feasible to predict tumor progression from visit A to visit C using a model trained by the information from visit A to visit B. However, the trained model failed when we tried to predict tumor progression from visit B to visit C, though it is clinically more important. A closer look at the MRI scans revealed that histograms of MRI scans such as T1, T2, FLAIR etc taken at different times have slight shifts or different shapes. This is because those MRI scans are qualitative instead of quantitative so MRI scans taken at different times or by different scanners might have slightly different scales or have different homogeneities in the scanning region. In this paper, we presented research to overcome this difficulty. The overall goal of this study is to assess brain tumor progression by exploring two patients' complete MRI records scanned during their visits in the past two years. There are ten MRI series, including FLAIR, T1-weighted, post-contrast T1-weighted, T2-weighted and five DTI derived MRI volumes, ADC, FA, Max, Min and Middle Eigen Values for each visit. After registering all series to the corresponding DTI scan at the first visit, we applied a histogram matching algorithm to none-DTI MRI scans to match their histograms to those of the corresponding MRI scans at the first visit. DTI derived series are quantitative and do not require the histogram matching procedure. A machine learning algorithm was then trained using the data containing information from visit A to visit B, and the trained model was used to predict tumor progression from visit B to visit C. An average of 71% pixel-wise accuracy was achieved for tumor progression prediction from visit B to visit C.

7963-102, Poster Session

Computer-aided tracking of MS lesions

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The location, size and shape of Multiple Sclerosis (MS) lesions are often used to diagnose and track disease progression. We have improved our lesion-browsing tool that allows users to automatically locate successive significant lesions in a MRI stack. In addition, an automatic alignment feature was implemented to facilitate comparisons across stacks. A lesion stack is formed that can be browsed independently or in tandem with the image windows. Lesions of interest can then be measured, rendered and rotated. Multiple windows allow the viewer to compare the size and shape of lesions from the MRI images of the same patient taken at different time intervals. This should provide a valuable tool for computer-aided diagnosis and disease tracking.

7963-103, Poster Session

Computer-aided assessment of pulmonary disease in novel swine-origin H1N1 influenza on CT

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The 2009 pandemic is a global outbreak of novel H1N1 influenza. Radiologic images can be used to assess the presence and severity of pulmonary infection. We develop a computer-aided assessment system

to analyze the CT images from Swine-Origin Influenza A (S-OIV) novel H1N1 cases. The technique is based on the analysis of lung texture patterns and classification using a support vector machine (SVM). Pixel-wise tissue classification is computed from the SVM value. The method was validated on four H1N1 cases and ten normal cases. We demonstrated that the technique can detect regions of pulmonary abnormality in novel H1N1 patients and differentiate these regions from visually normal lung (area under the ROC curve is 0.993). This technique can also be applied to differentiate regions infected by different pulmonary diseases.

7963-104, Poster Session

Lung ventilation analysis using deformable registration in Xe-enhanced CT images

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To analyze regional lung ventilation using two-phase xenon CT with wash-in and wash-out periods, we propose an accurate and fast deformable registration and ventilation imaging. First, to restrict the registration to the lung parenchyma, the left and right lungs are segmented. Second, to correct position difference and local deformation of the lungs, affine and demon-based deformable registrations are performed. The lungs of wash-out image are globally aligned to the wash-in image by narrow-band distance propagation based affine registration and nonlinearly deformed by a demon algorithm using a combined gradient force and active cells. Finally, to assess the regional lung ventilation, color-coded ventilation map is generated by image subtraction and homogeneous/heterogeneous enhancement. Experimental results show that our accurate and fast deformable registration corrects not only positional difference but also local deformation. Our ventilation imaging using density subtraction and homogeneous/heterogeneous enhancement helps the analysis of regional lung ventilation.

7963-105, Poster Session

Lung tumours segmentation on CT scans using sparse field active model

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Manual segmentation of lung tumours is observer-dependent and time consuming, which are major limitations for use in clinical trials. In this paper we present a semi-automated segmentation method, which is more time-efficient and less operator dependent than manual segmentation. We developed a semi-automated algorithm to segment lung tumours on chest computed tomography (CT) images using shape constrained multi-thresholding (SCMT) and sparse field active model (SFAM) techniques. For each 2D slice of CT tumour image, an initial contour was generated using SCMT. This initial contour was then deformed using SFAM. Seven forces were utilized in the SFAM technique to control the deformation namely: global region, local region, curvature, edge information, smoothness, anchor, and partial volume. The proposed algorithm was tested with 70 CT tumour slices (19 well-defined tumours (WD) located centrally in the lung parenchyma without significant vasculature and 51 vascularized or juxtapleural tumours (VJ)). Our results showed that the initial contour generated by the SCMT technique was sufficient to segment the well-defined (WD) tumours without any deformation. However, the deformation using SFAM was required to segment vascularized or juxtapleural (VJ) tumours. The results of the proposed segmentation algorithm were evaluated by comparing them to manual segmentation using the dice coefficient (DC). The average DC was 96.3±1.1% and 95.2±1.6% for WD and VJ tumour images respectively. The average DC obtained for the entire data set was 95.5±1.6%, which shows that the proposed algorithm can accurately segment lung tumours and can be utilized for monitoring tumours response to treatment.

7963-106, Poster Session

Automated segmentation of pulmonary nodule depicted on CT images

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Accurate delineation of pulmonary nodules depicted on CT images medical images plays an important role in computer-aided detection/diagnosis of lung cancer because it may reduce false positives and/or negatives in lung cancer detection and allow diagnosis of malignancy based on volumetric measurement. However, the existence of various diseases, image noise or artifacts, and individual anatomical variety often makes this task challenging. In this study, an efficient computational geometry approach is introduced to segment pulmonary nodules. The underlying idea is to estimate the three-dimensional boundary of a nodule in question by analyzing the shape characteristics of its surrounding tissues in geometric space. Given a seed point or a specific location where a suspicious nodule may be, three steps are involved in this approach. First, a sub-volume centered at this seed point is extracted and the contained anatomy structures are modeled in the form of a triangle mesh surface. Second, a "visibility" test combined with a shape classification algorithm based on principal curvature analysis removes regions determined not to belong to nodule boundaries by specific rules. This step results in a partial surface of a nodule boundary. Third, an interpolation/extrapolation based shape reconstruction procedure is used to estimate a complete nodule surface by representing the partial surface as an implicit function. The preliminary experiments on 36 annotated CT examinations depicting 167 verified nodules with four radiologists' manual delineations demonstrated that this scheme had advantages such as accuracy, efficiency, easy of implementation, and low sensitivity to a seed point.

7963-107, Poster Session

A study on quantifying COPD severity by combining pulmonary function tests and CT image analysis

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This paper describes a novel method that can evaluate chronic obstructive pulmonary disease (COPD) severity by combining measurements of pulmonary function tests and measurements obtained from CT image analysis. There is no cure for COPD. However, with regular medical care and consistent patient compliance with treatments and lifestyle changes, the symptoms of COPD can be minimized and progression of the disease can be slowed. Therefore, many diagnosis methods based on CT image analysis have been proposed for quantifying COPD. Most of diagnosis methods for COPD extract the lesions as low-attenuation areas (LAA) by thresholding and evaluate the COPD severity by calculating the LAA in the lung (LAA%). However, COPD is usually the result of a combination of two conditions, emphysema and chronic obstructive bronchitis. Therefore, the previous methods based on only LAA% do not work well. The proposed method utilizes both of information including the measurements of pulmonary function tests and the results of the chest CT image analysis to evaluate the COPD severity. In this paper, we utilize a multi-class AdaBoost to combine both of information and classify the COPD severity into five stages automatically. The experimental results revealed that the accuracy rate of the proposed method was 88.9% (resubstitution scheme) and 64.4% (leave-one-out scheme).

7963-108, Poster Session

Classification algorithm of lung lobe for lung disease cases based on multislice CT images

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With the development of multi-slice CT technology, to obtain an accurate 3D image of lung field in a short time is possible. To support that, a lot of image processing methods need to be developed. In clinical setting for diagnosis of lung cancer, it is important to study and analyse lung structure. Therefore, classification of lung lobe provide useful information for lung cancer analysis. In this report, we describe algorithm which classify lungs into lung lobes for lung disease cases from multi-slice CT images. The classification algorithm of lung lobes is efficiently carried out using information of lung blood vessel, bronchus, and interlobar fissure. Applying the classification algorithms to multi-slice CT images of 20 normal cases and 5 lung disease cases, we demonstrate the usefulness of the proposed algorithms.

7963-109, Poster Session

Segmentation of lung fields using Chan-Vese active contour model in chest radiographs

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A CAD tool for chest radiographs consists of several procedures and the very first step is segmentation of lung fields. We develop a novel methodology for segmentation of lung fields in chest radiographs that can satisfy following two requirements. First, we aim to develop a segmentation method that does not need a training stage with manual estimation of anatomical features in a large training set of images. Secondly, for the ease of implementation, it is desirable to apply a well established model that is widely used for various image-partitioning practices. Chan-Vese active contour model, which is based on Mumford-Shah functional in the level set framework, is applied for segmentation of lung fields. With the use of this model, segmentation of lung fields can be done without detailed prior knowledge on the radiographic anatomy of the chest, yet in some chest radiographs, the trachea regions are unfavorably segmented out in addition to the lung field contours. To eliminate artifacts from the trachea, we locate the upper end of the trachea, find a vertical center line of the trachea and delineate it, and then brighten the trachea region to make it less distinctive. The segmentation process is finalized by subsequent morphological operations. We randomly select 30 images from the Japanese Society of Radiological Technology image database to test the proposed methodology and the results are shown. We hope our segmentation technique can help development of CAD tools, especially for emerging chest radiographic imaging techniques such as dual energy radiography and chest tomosynthesis.

7963-110, Poster Session

Catheter detection and classification on chest radiographs: an automated prototype computer-aided detection (CAD) system for radiologists

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Chest radiographs are the quickest and safest method to check placement of man-made medical devices placed in the body like catheters, stents and pacemakers etc out of which catheters are the most commonly used devices. The two most often used catheters especially in the ICU are the Endotracheal (ET) tube used to maintain patient's airway and the Nasogastric (NG) tube used to feed and administer drugs. Tertiary ICU's typically generate over 250 chest radiographs per day to confirm tube placement. Incorrect tube placements can cause serious complications and can even be fatal. The task of identifying these tubes on chest radiographs is difficult for radiologists and ICU personnel given the high volume of cases. This motivates the need for an automatic detection system to aid radiologists in processing these critical cases in a timely fashion while maintaining patient safety. To-date there has been very little research in this area. This paper develops a new fully automatic prototype computer-aided detection (CAD) system for detection and classification of catheters on chest radiographs using a combination of template matching, morphological processing and region growing. The preliminary evaluation was carried out on 25 cases. The prototype CAD system was able detect ET and NG tubes with sensitivity of 73.7% and 76.5% respectively and with specificity of 91.3% and 84.0% respectively. The results from the prototype system show that it is feasible to automatically detect both catheters on chest radiographs, with the potential to significantly speed the delivery of imaging services while maintaining high accuracy.

7963-111, Poster Session

Automatic detection of lung vessel bifurcation in thoracic CT Images

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Computer-aided diagnosis (CAD) systems for detection of lung nodules have been an active topic of research for last few years. It is desirable that a CAD system should generate very low false positives (FPs) while maintaining high sensitivity. This work aims to reduce the number of false positives occurring at vessel bifurcation point. FPs occur quite frequently on vessel branching point due to its shape which can appear locally spherical due to the intrinsic geometry of intersecting tubular vessel structures combined with partial volume effects and soft tissue attenuation appearance surrounded by parenchyma.

We propose a model-based technique for detection of vessel branching points using skeletonization, followed by branch-point analysis. We first perform vessel structure enhancement using a multi-scale Hessian filter to accurately segment tubular structures of various sizes and is thresholded to get binary vessel structure segmentation. A modified Reebgraph [7] is applied then to extract the critical points of structure, and are joined by a nearest neighbor criterion to obtain complete skeletal model of vessel structure. The skeletal model is then traversed to identify branch points, and metrics like individual branch length, number of branches and angle between various branches. Results on 80 sub-volumes consisting of 60 actual vessel-branching and 20 solitary solid nodules show that our algorithm identified correctly vessel branching points for 57 sub-volumes and misclassified 2 nodules as vessel branching. Thus, this technique has potential in correct identification of vessel branching points, and could be useful in false positive reduction in a lung CAD system.

7963-112, Poster Session

Hybrid CAD scheme for lung nodule detection in PET/CT images

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Lung cancer is the leading cause of death among male in the world. To reduce the cancer-related death, it is essential to detect and treat it at an early stage. PET/CT is an imaging technique that has functional and anatomical information; it is useful for the detection of early lung cancer. However, radiologist has to examine using the large number of images. Therefore reduction of radiologist's load is strongly desired. In this study, hybrid CAD scheme has been proposed to detect lung nodule in PET/CT images. Proposed method detects the lung nodule from both CT and PET images. As for the detection in CT images, solitary nodules are detected using cylindrical filter that we developed. In PET images, highly uptake regions are detected by thresholding based on standard uptake value (SUV). After both detections, FP reduction is performed using seven characteristic features and Support Vector Machine. Finally these results are integrated, and candidate regions are obtained. In the experiment, we evaluated proposed method using 20 cases of PET/CT images that were obtained for the cancer-screening program. We evaluated true positive fraction (TPF) and FP/case. As a result, TPFs of CT and PET detections were 0.55 and 0.59, respectively. However, by integrating the both results, TPF was improved to 0.93. Moreover, the number of FPs/case of proposed scheme was 11.2. In summary, these results indicate that our method may be useful for the lung cancer detection using PET/CT images.

7963-113, Poster Session

Classification of texture patterns in CT lung imaging

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Since several lung diseases can be potentially diagnosed based on the patterns of lung tissue observed in medical images, automated texture classification can be useful in assisting the diagnosis. In this paper, we propose a methodology for discriminating between various types of normal and diseased lung tissue in computed tomography (CT) images that utilizes Vector Quantization (VQ), an image compression technique, to extract discriminative texture features. Rather than focusing on images of the entire lung, we direct our attention to the extraction of local descriptors from individual regions of interest (ROIs) as determined by domain experts. After determining the ROIs, we generate 'locally optimal' codebooks representing texture features of each region using the Generalized Lloyd Algorithm. We then utilize the codeword usage frequency of each codebook as a discriminative feature vector for the region it represents. We compare k-nearest neighbor, support vector machine and neural network classification approaches using the normalized histogram intersection as a similarity measure. The classification accuracy reached up to 98% for certain experimental settings, indicating that our approach may potentially assist clinicians in the interpretation of lung images and facilitate the investigation of relationships among structure, texture and function or pathology related to several lung diseases.

7963-114, Poster Session

Toward the detection of abnormal chest radiographs the way radiologists do it

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Current efforts to provide Computer Aided Detection (CADe) seek to employ feature extraction, pattern recognition, and machine learning algorithms to aid radiologists in detecting abnormalities in medical images. However, these computational methods are based upon the assumption that there are distinct classes of abnormalities, and that each class has some distinguishing features that set it apart from other classes. However, abnormalities in chest radiographs tend to be very heterogenous. Thoracic radiologists have found it more effective to develop a sense of what is normal, so that anything that is abnormal will attract their attention. This approach to radiology suggests that researchers who are seeking to provide CADe tools might find it more productive to develop algorithms that learn to recognize normal chest radiographs (in all their various forms) based on large libraries of features that have been extracted from normal chest radiographs. However, features that might be normal in one region of a chest might be abnormal in another region. So, to be successful, it is necessary to develop some method for extracting features based on the anatomical coordinates, rather than the pixel coordinates in radiographs. This paper describes a method that can be used to guide the extraction of features based on anatomical coordinates rather than image coordinates.

7963-115, Poster Session

Automated detection of pulmonary nodules in CT: false positive reduction by combining multiple classifiers

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This study investigated various classifier combination methods for improving the performance of a CAD system for pulmonary nodule detection in CT. We employed CT cases from the publicly available LIDC dataset, which included 85 CT cases with 110 nodules. We used six individual classifiers for nodule detection in CT. The six classifiers included linear discriminant analysis (LDA), quadratic discriminant analysis (QDA), artificial neural network (ANN), and three types of support vector machines (SVM). Five information-fusion methods were employed to combine the classifiers' outputs for improving detection performance. The five combination methods included two supervised (likelihood ratio method and neural network), and three unsupervised ones (the mean, the product, and the majority-vote of the output scores from the six individual classifiers). Leave-one-case-out was employed to train and test individual classifiers and supervised combination methods. At a sensitivity of 80 %, the numbers of false positives per case for the six individual classifiers were 6.1 for LDA, 19.9 for QDA, 8.6 for ANN, 23.7 for SVM-dot, 17.0 for SVM-poly, and 23.35 for SVM-ANOVA; the numbers of false positives per case for the five combination methods were 3.4 for the majority-vote rule, 6.2 for the mean, 5.7 for the product, 9.7 for the neural network, and 28.1 for the likelihood ratio method. The majority-vote rule achieved higher performance levels than other combination methods. It also achieved higher performance than the best individual classifier, which is not the case for other combination methods.

7963-116, Poster Session

Scan-rescan reproducibility of CT densitometric measures of emphysema

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This study investigated the reproducibility of HRCT densitometric measures of emphysema in patients scanned twice one week apart.

24 emphysema patients from a multicenter study were scanned at full inspiration (TLC) and expiration (RV), then again a week later for four scans total. Scans for each patient used the same scanner and protocol, except for tube current in three patients.

Lung segmentation with gross airway removal was performed on the scans. Volume, weight, mean lung density (MLD), relative area under -950HU (RA-950), and 15th percentile (PD-15) were calculated for TLC, and volume and an air-trapping mask (RA-air) between -950 and -850HU for RV. For each measure, absolute differences were computed for each scan pair, and linear regression was performed against volume difference in a subgroup with volume difference <500mL.

Two TLC scan pairs were excluded due to segmentation failure. The

mean lung volumes were 5802 +/- 1420mL for TLC, 3878 +/- 1077mL for RV. The mean absolute differences were 169mL for TLC volume, 316mL for RV volume, 14.5g for weight, 5.0HU for MLD, 0.66p.p. for RA-950, 2.4HU for PD-15, and 3.1p.p. for RA-air. The <500mL subgroup had 20 scan pairs for TLC and RV. The R2 values were 0.8 for weight, 0.60 for MLD, 0.29 for RA-950, 0.31 for PD-15, and 0.64 for RA-air.

Our results indicate that considerable variability exists in densitometric measures over one week that cannot be attributed to breathhold or physiology. This has implications for clinical trials relying on these measures to assess emphysema treatment efficacy.

7963-117, Poster Session

Improving the channeler ant model for lung CT analysis

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The Channeler Ant Model (CAM) is an algorithm based on virtual ant colonies, conceived for the segmentation of complex structures with different shapes and intensity in a 3D environment. It exploits the natural capabilities of virtual ant colonies to modify the environment and communicate with each other by pheromone deposition.

The CAM has been validated with the segmentation of 3D artificial objects and it has already been successfully applied to the lung nodules detection in Computed Tomography images within the ANODE09 challenge.

The model improvements for the segmentation of pleural nodules and the results on the 5 scans with annotations made publicly available by ANODE09 and on a database of 20 low dose high resolution CT scans (GS20) provided and annotated by the ITALUNG_CT screening project are presented.

The pre-classification performance reaches 84.6% sensitivity (33/39 nodules) with 52.2 FP/scan and 84.2% sensitivity (32/38 nodules) with 56 FP/scan on the ANODE09 and GS20 samples, respectively. The missed nodules are all structures attached to the bronchial or vascular tree.

A simple selection based on the sphericity and volume as a function of the distance from the lung cage provides the following results at the opposite side of the FROC range: 34.2% (46.1%) sensitivity at 0.65 (0.4) FP/scan for the GS20 (ANODE09) sample.The false positive reduction via feed forward neural network is ongoing.

7963-118, Poster Session

Comparative performance analysis of stained histopathology specimens using RGB and multispectral imaging

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A performance study was conducted to compare classification accuracy using both multispectral imaging (MSI) and standard bright-field imaging (RGB) to characterize breast tissue microarrays. The study was primarily focused on investigating the classification power of texton features for differentiating cancerous breast TMA discs from normal. The feature extraction algorithm includes two main processes: texton library training and histogram construction. First, two texton libraries were built for multispectral cubes and RGB images respectively, which comprised the training process. Second, texton histograms from each multispectral cube and RGB image were used as testing sets. Finally, within each spectral band, exhaustive feature selection was used to search for the combination of features that yielded the best classification accuracy using the pathologic result as a golden standard. Support vector machine was applied as a classifier using leave-one-out cross-validation. The spectra carrying the greatest discriminatory power were automatically chosen and a majority vote was used to make the final classification. The study included 122 breast TMA discs that showed poor classification power based on simple visualization of RGB images. Use of multispectral cubes showed improved sensitivity and specificity compared to the RGB images (85% sensitivity & 85% specificity for MSI vs. 75% & 65% for RGB). This study demonstrates that use of texton features derived from MSI datasets achieve better classification accuracy than these derived from RGB datasets. This study demonstrated that MSI provided statistically significant improvements in automated analysis of single-stained bright-field images. Future work will examine MSI performance in assessing multi-stained specimens.

7963-119, Poster Session

Automatic location of microscopic focal planes for computerized stereology

D. T. Elozory, O. P. Bonam, K. Kramer, D. B. Goldgof, L. O. Hall, O. Mangual, P. R. Mouton, Univ. of South Florida (United States)

For integrated hardware-software systems that apply design-based stereology to biological tissue, there are two primary applications for an autofocusing function. First, the system must find the in-focus optical planes, at the upper and lower surfaces of stained tissue sections; second, the system must find the focal plane for the start and end of stained objects within a Z-stack of optical planes through tissue sections. In contrast to traditional autofocus algorithms that find a global maximum on the focus curve, our goal was to find the sharp “knees” that represent two “just out-of-focus” focal planes when moving from unfocused to focused regions on the upper surface of the tissue section; and, when moving from the focused to unfocused regions on the lower surface.

We compared the performance of seven focus algorithms to locate the top and bottom focal planes sections through 381 images from 30 Z-stacks. The Threshold Absolute Gradient algorithm outperformed all others, achieving 1 µm and 15 µm as the between-focal plane distance and the average section thickness, respectively. This algorithm correctly identified the top or bottom focal plane within an average of 1 µm on our training data and 1.5 µm on our test data.

Autofocusing is a critical first step in the automatic collection of stereology data. With the successful identification of an algorithm to locate in-/out-of-focus planes, the process to automatically quantify first- and second-order stereology parameters of biological objects is possible.

7963-120, Poster Session

Local distribution fitting-based pixel labeling for histology image segmentation

L. He, L. R. Long, S. K. Antani, G. R. Thoma, National Institutes of Health (United States)

This paper presents a new pixel labeling algorithm for histology image segmentation. For each image pixel, a Gaussian mixture model is applied to estimate its neighborhood intensity distributions. With the local distribution fitting results, a set of pixels with all different source classes (e.g. nuclei, stroma, connective tissue, and background) in their neighborhoods are identified as the seeds for pixel labeling. A seed pixel is labeled by measuring its intensity distance to each of its neighborhood distributions, and the one with the shortest distance is selected to label the seed. For non-seed pixels, we propose two different labeling schemes: global voting and local clustering. In global voting each seed classifies a non-seed pixel into one of the seed’s local distributions, i.e., it casts one vote; the final label for the non-seed pixel is the class which gets the most votes, across all the seeds. In local clustering, each non-seed pixel is labeled by one of its own neighborhood distributions. Because two or more local distributions in a non-seed pixel neighborhood may be produced by the same source class, we firstly identify the source classes of the pixel local distributions by comparing them with those of the seeds. The pixel can then be labeled by the identified local clusters. With both labeling schemes, experiments on a set of uterine cervix histology images show encouraging performance of our algorithm when compared with traditional multithresholding and K-means clustering, as well as state-of-the-art mean shift clustering, multiphase active contours, and Markov random field-based algorithms.

7963-121, Poster Session

Image-based histologic grade estimation using stochastic geometry analysis

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Background: Low reproducibility of histologic grading of breast carcinoma due to its subjectivity has traditionally diminished the prognostic value of histologic breast cancer grading. The objective of this study is to assess the effectiveness and reproducibility of grading breast carcinomas using automated computerized image analysis of histology images. The automated grading is based on stochastic geometry shape analysis of the cellular spatial structures present in the carcinomas.

Methods: We used histology images stained with Hematoxylin & Eosin (H&E) from invasive mammary carcinoma, no special type cases as a source domain and study environment. We developed a customized hybrid semi-automated segmentation algorithm to cluster the raw image data and reduce the image domain complexity to a binary representation, with the foreground representing regions of high density of malignant cells. A second algorithm was developed to apply stochastic geometry and texture analysis measurements to the segmented images. The application of the measurements transforms the original color images into a histogram representation (a shape distribution) that captures discriminating geometric properties in the images that allows us to estimate the various histological grades.

Results: Computational results were compared against known histological grades assigned by a pathologist. The Earth Mover's Distance (EMD) similarity metric and the K-Nearest Neighbors (KNN) classification algorithm provided correlations between the high-dimensional set of shape distributions and a priori known histological grades.

Conclusion: Computational pattern analysis of histology based on stochastic geometry shows promise as an effective software tool in breast cancer histological grading and therefore other forms of computer-aided diagnosis.

7963-122, Poster Session

Glandular object based tumor morphometry in H&E biopsy samples for prostate cancer prognosis

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Morphological and architectural characteristics of primary prostate tissue compartments, such as epithelial nuclei (EN) and cytoplasm, provide critical information for cancer diagnosis, prognosis and therapeutic response prediction. The subjective and variable Gleason grade assessed by expert pathologists in Hematoxylin and Eosin (H&E) stained specimens has been the standard for prostate cancer diagnosis and prognosis. We propose a novel morphometric, glandular object-oriented image analysis approach for the robust quantification of H&E prostate biopsy images.

We demonstrate the utility of features extracted through the proposed method in predicting disease progression post treatment in a multi-institution cohort of 1027 patients. The biopsy based features were univariately predictive for clinical response post therapy; with concordance indexes (CI) 0.4 or 0.6. In multivariate analysis, a glandular object feature quantifying tumor epithelial cells not directly associated with an intact tumor gland was selected in a model incorporating preoperative clinical data, protein biomarker and morphological imaging features. The model achieved a CI of 0.73 in validation, which was significantly higher than a CI of 0.69 for the standard multivariate model based solely on clinical features currently used in clinical practice.

This work presents one of the first demonstrations of glandular object based morphological features in the H&E stained biopsy specimen to predict disease progression post primary treatment. Additionally, it is the largest scale study of the efficacy and robustness of the proposed features in prostate cancer prognosis.

7963-123, Poster Session

Towards automated quantification of biological microstructures using unbiased stereology

O. P. Bonam, D. T. Elozory, K. Kramer, D. B. Goldgof, L. O. Hall, O. Mangual, P. R. Mouton, Univ. of South Florida (United States)

Quantitative analysis of biological microstructures using unbiased stereology plays a large and growing role in bioscience research. The aim of the present project is to add a fully automatic, high-throughput mode to a commercially available, computerized stereology device (Stereologer). The current method for estimation of first- and second order parameters of biological microstructures requires a trained user to manually select objects of interest (cells, fibers etc.,) while focusing through the depth of a stained tissue section. The proposed approach uses a combination of color and gray-level processing. Thirty stacks of images were automatically acquired at varying depth of tissue sections at different locations on the sample. Color processing was used to identify the objects of interest and grey-level processing to assign a unique identity and to enumerate the objects. The color processing step involved training on the images to obtain the threshold range for a specific object stained with a given method, followed by color space conversion to threshold the image using hue and saturation channels (RGB to HSI). Finally, a region-growing approach was used to identify and count the number of objects. This automatic approach achieved an overall object detection rate of 93.27%. In order to classify across a range of object types, future work will apply additional classification modules on segmented objects of interest. Thus, these results support the view that automatic image analysis, combined with unbiased sampling and parameter estimation, can support accurate and efficient automatic quantification of biological objects in stained tissue sections.

7963-124, Poster Session

A distributed architecture for a loosely coupled virtual microscopy system

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Virtual microscopy systems are typically implemented following standard client-server architectures, under which the server must store a huge quantity of data. The server must attend requests from many clients as several Regions of Interest (RoIs) at any desired levels of magnification and quality. The communication bandwidth limitation, the I/O image data accesses, the decompression processing and specific raw image data operations such as clipping or zooming to a desired magnification, are highly time-consuming processes. All this together may result in poor navigation experiences with annoying effects produced by the delayed response times. This article presents a virtual microscope system with a distributed storage system and parallel processing. The system attends each request in parallel, using a clustered java virtual machine and a distributed filesystem. Images are stored in JPEG2000 which allows natural parallelization by splitting the image data into a set of small codeblocks that contain independent information of an image patch, namely, a particular magnification, a specific image location and a pre-established quality level. The compressed J2K file is replicated within the Distributed Filesystem, providing fault tolerance and fast access. A requested RoI is split into stripes which are independently decoded for the distributed filesystem, using an index file which allows to easily locate the particular node containing the required set of codeblocks.

When comparing with a non-parallelized version of the virtual microscope software, user experience is improved by speeding up RoI displaying in about 60% using two computers.

7963-125, Poster Session

Counting of RBCs and WBCs in noisy normal blood smear microscopic images

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This work focuses on the segmentation and counting of Peripheral blood smear particles which play a vital role in medical diagnosis. Our approach profits from some powerful processing techniques. Firstly, the method used for denoising an image of a blood smear is based on the Bivariate wavelet. Secondly, the technique for edge preservation is taken from the Kuwahara filter. Thirdly, a new binarization output is introduced by merging the Otsu and Niblack methods. We have also applied an efficient step-by-step procedure to determine solid binary objects by merging modified binary, edged images and modified Chan-Vese active contours. The separation of White Blood Cells (WBCs) from Red Blood Cells (RBCs) into two sub-images based on the RBC (blood's dominant particle) size estimation is a critical step. Using Granulometry, we get an approximation of this RBC size. The proposed separation algorithm is an iterative mechanism which is based on morphological theory, saturation amount and RBC size. A primary aim of this work is to introduce an accurate mechanism for segmenting blood smear particles. This is being accomplished using the Immersion Watershed algorithm which counts red and white blood cells separately. To evaluate the capability of the algorithm, experiments were conducted on normal blood smear images collected primarily from a specified blood database as well as from other sources. Finally, this method was compared to other published approaches and found to have lower complexity and better performance in its constituent steps; hence, it has a better overall performance

7963-126, Poster Session

Direct visualization of regions with lowered bone mineral density in dual-energy CT images of vertebrae

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Dual-energy computed tomography (DECT) has been introduced already more than 20 years ago. In contrast to conventional CT where an X-ray source with one single peak energy is used, DECT uses two different peak energies aiming on a better material differentiation. The purpose of this work is the direct visualization of regions with lowered bone mineral density (BMD) in vertebrae of the spine employing DECT image data. For this, based on an existing biophysical model the expected differences between the used 80 and 140 kV images for typical BMD value ranges given in the literature are computed. Voxels representing low BMD values are mapped to color for a direct visualization of these low density regions. We evaluated our methods with image data acquired from 14 human cadaver vertebrae originating from two osteoporosis patients. We observed a very good matching between the highlighted regions in the BMD enhanced image and regions of lowered BMD for all data sets. In contrast to existing methods it does not require that the image region which contains the trabecular bone is delineated. Thus, the BMD computation is simplified and sped up. Its further strength is the fact that the density information is added to the displayed image by virtually not changing the appearance of the image.

7963-127, Poster Session

Automated localization and classification of vertebra landmarks in MRI images

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The identification of key landmark points in an MR spine image is an important step for tasks such as vertebra counting. In this paper, we propose a template matching based approach for automatic detection of two key landmark points, namely the second cervical vertebra (C2) and the sacrum from sagittal MR images. The approach is comprised of an approximate localization of vertebral column followed by matching with appropriate templates in order to detect/localize the landmarks. A straightforward extension of the work described here is an automated classification of spine section(s). It also serves as a useful building block for further automatic processing such as extraction of regions of interest for subsequent image processing and also in aiding the counting of vertebra.

7963-128, Poster Session

Segmentation of knee injuries swelling on infrared images

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Interpretation of medical infrared images is complex due to thermal noise, absence of textures, and limited temperature differences of pathological zones. Acute inflammatory response is a characteristic symptom of some knee injuries like, anterior cruciate ligament sprains, muscle or tendons strains, and meniscus tear. Whereas artificial coloring of the original grey level images may permit to visually spot the extent of inflamed areas, their automated segmentation remains a challenging problem. This paper presents a hybrid segmentation algorithm, to assess the extent of inflammation after knee injury, in terms of temperature variations and surface shape.

It is based on the intersection of rapid color segmentation and homogeneous region segmentation, to which a Laplacian of Gaussian filter is applied. While rapid color segmentation enables to properly detect the observed swelling area core, homogeneous regions segmentation identifies possible inflammation zones, combining homogeneous grey level and hue area segmentation. The hybrid segmentation algorithm compares potential inflammation regions partially detected by each method to identify overlapping areas. Noise filtering and edge segmentation are then applied to those common zones in order to segment the swelling surfaces of the injury. Experimental results on images of a patient with anterior cruciate ligament sprain show the improved performance of the hybrid algorithm with respect to its separated components. The main contribution of this work is a meaningful automatic segmentation of abnormal skin temperature variations, on infrared thermography images of knee injury swelling.

7963-129, Poster Session

Computer-aided tumor detection stemmed from the fuzzification of the Dempster-Shafer theory

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In decision making processes where we have to deal with epistemic uncertainties, the Dempster-Shafer theory (DST) of evidence and fuzzy logic have gained prominence as the methods of choice over traditional

probabilistic methods. The DST is unfortunately known to give wrong results in situations of high conflict. While some methods have been proposed in the literature for improving the DST, such as the weighted DST which assumes that we have some information about the relative reliabilities of the classifiers, we opted to incorporate fuzzy concepts in the DST framework. This work was motivated by the desire to improve detection performance of a Computer-Aided detection (CAD) system under development for the detection of tumors in Positron Emission Tomography (PET) images by fusing the output of multiple classifiers such as the SVM and LDA classifiers. A first implement based on a simple binary fusion scheme gave a somewhat promising result of 69% true detection with an average of 2.5 false positive detections per 3D image (FPI). These results prompted the use of the DST which resulted in 92% detection sensitivity and 25 FPI. As a way of further reducing the false detections, we chose to tackle the limitations inherent to the DST by principally applying fuzzy techniques in defining the hypotheses and experimenting with new combination rules. The best result of this modified DST approach has been a 92% true tumor detection with 12 FPI; indicating a reduction by a factor of 2 of the false detections while maintaining high sensitivity.

7963-130, Poster Session

Analysis of transient thermal images to distinguish melanoma from dysplastic nevi

M. Pirtini Cetingul, H. E. Cetingul, C. Herman, The Johns Hopkins Univ. (United States)

We have recently developed a thermal infrared (IR) imaging system that allows accurate measurements of transient temperature distributions of the skin surface. It relies on active infrared imaging for the characterization of skin lesions. We hypothesize that malignant pigmented lesions with increased proliferative potential generate quantifiable amounts of heat and possess an ability to reheat more quickly than surrounding normal skin, thereby creating a marker of melanoma lesions (vs. non-proliferative nevi). In our previous studies, we demonstrate that the visualization and measurement of the transient thermal response of the skin to a cooling excitation can aid the identification of skin lesions of different origin. In this work, we present a multimodal image analysis strategy including involuntary body/limb motion correction and interactive lesion segmentation for quantifying the transient thermal response with high accuracy. Such an imaging system capable of distinguishing benign from malignant pigmented lesions is expected to improve the diagnostic accuracy and sensitivity for melanoma as well as other skin cancers, while decreasing the number of unnecessary biopsies. The proposed system is thereby tested in a pilot patient study in which patients who possess a pigmented lesion with a clinical indication for biopsy are selected to participate. After scanning, biopsying, and grading the lesions for malignant potential, we observed that the results of our quantitative diagnostic approach match well with the biopsy results.

7963-131, Poster Session

BCC skin cancer diagnosis based on texture analysis techniques

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Skin cancer is usually diagnosed by a biopsy microscopy procedure. In this paper, we studied the feasibility of automatic diagnosis for the Basal Cell Carcinoma (BCC) skin cancer based on optical images taken from suspicious skin regions. Standard texture analysis and machine learning techniques had been utilized to classify images into normal or BCC cases. We first extracted the Run Length Matrix and Haralick texture features from the images and used a feature selection algorithm to identify the most effective feature set for the diagnosis. We then utilized a Multi-Layer Perceptron (MLP) classifier to classify the images to BCC or normal cases. Experimental results on 319 images showed that detecting BCC cancer based on optical images is feasible. The best sensitivity and specificity we achieved on our data set were 94% and 95%, respectively.

7963-132, Poster Session

Computer-aided diagnosis for prostate cancer detection in the peripheral zone via multisequence MRI

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We propose a Computer Assisted Diagnosis Interview (CADi) scheme for determining a likelihood measure of prostate cancer presence in the peripheral zone (PZ) based on multisequence magnetic resonance imaging, including T2-weighted (T2w), diffusion-weighted (DWI) and dynamic contrast-enhanced (DCE) MRI at 1.5 Tesla (T). Based on a feature set derived from the gray level images, including first order statistics, Haralick's features, gradient features, semi-quantitative and quantitative (pharmacokinetic modeling) dynamic parameters, we trained and compared four kinds of classifiers: Support Vector Machine (SVM), Linear Discriminant Analysis (LDA), k-Nearest Neighbours (KNN) and Naïve Bayes (NB). The aim is twofold: we try to discriminate between the relevant features as well as creating an efficient classifier using these features. The database consists of 23 radical prostatectomy patients. Using histologic sections as the gold standard, both cancers and non-malignant tissues (suspicious and clearly benign) were annotated in consensus on all MR images by two radiologists, a histopathologist and a researcher. These annotations were used as regions of interest (ROIs) to create our CADi: outputs of the classifiers measuring the likelihood of malignancy of a given suspected region. Diagnostic performances were evaluated based on a ROC curves analysis. From the outputs of all evaluated feature selection methods on the test bench, we discriminated a restrictive set of about 25 highly informative features. Quantitative evaluation of the diagnostic performance yielded to an AUC of 0.83, suggesting that a CADi system based on multisequence MRI could be capable of differentiating prostate cancer from non-malignant tissues in the PZ.

7963-133, Poster Session

A CAD system based on multi-parametric analysis for cancer prostate detection on DCE-MRI

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Computer-aided diagnosis systems (CAD) using dynamic contrast enhanced MRI data (DCE-MRI) may be developed to help localize prostate cancer and guide biopsy, avoiding random sampling of the whole gland. In the future CAD systems will be able to guide focal treatments such as cryotherapy and high intensity focused ultrasound.

The purpose of this study was to present a DCE-MRI CAD system, which calculates the likelihood of malignancy in a given area of the prostate by combining model-based and model-free parameters. The dataset included 10 patients with prostate cancer, with a total of 13 foci of adenocarcinoma. The post-processing was based on the following steps: testing of registration quality, noise filtering, and extracting the proposed features needed to the CAD. Parameters with the best performance in discriminating between normal and cancer regions were selected by computing the area under the ROC curve, and by evaluating the

correlation between pairs of features. A 6-dimensional parameters vector was generated for each pixel and fed into a Bayesian classifier. The output was the probability of malignancy. The classification performance was estimated using the leave-one-out method.

The resulting area under the ROC curve was 0.899 (95%CI:[0.893-0.905]); sensitivity and specificity were 82.4% and 82.1% respectively at the best cut-off point (0.352).

Our preliminary results show that the system is accurate in detecting areas of the gland that are involved by tumour. Further studies will be necessary to confirm these promising preliminary results.

7963-134, Poster Session

Modeling photo-bleaching kinetics to map local variations in rod rhodopsin density

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In order to elucidate mechanisms of early retinal disease and evaluate strategies for their prevention better noninvasive image analysis tools are needed. Localized rod photoreceptor and rhodopsin losses are early changes in human photoreceptors observed in post mortem histology of retinas with age-related maculopathy. We noninvasively map local rod rhodopsin density through analysis of the brightening of the underlying lipofuscin autofluorescence (LAF) in confocal scanning laser ophthalmoscopy (cSLO) imaging sequences starting in the dark adapted eye and completed in ~25sec. In these sequences, the detected LAF increases up to 2-fold as rhodopsin absorption at 488nm is almost completely abolished by its bleaching.

After image registration, we apply to our cSLO movies analytical expressions for the kinetics of rhodopsin bleaching that Lamb validated using electroretinogram recordings in human. The retinal irradiance during cSLO LAF imaging provides virtually complete rhodopsin bleaching and therefore is insensitive to visual cycle time constant. We performed localized kinetic analysis at resolutions as small as a single pixel (10microns) and created high resolution maps of the local variations of the different fitted parameters within normal human retinas. We observe a strong correlation between spatial variations in computed rhodopsin density and the steady-state LAF, supporting the role of the A2E pathway in LAF.

Our new noninvasive imaging and analysis approach appears well-suited for identifying localized (~100microns) early changes in the rod photoreceptors and correlating them with localized RPE pathological changes seen in steady-state LAF images at exceptional spatial resolution.

7963-135, Poster Session

Identifying glaucoma with multi-fractal features from optical coherence tomography

P. Gunvant, Southern College of Optometry (United States); P. Y. Kim, K. M. Iftekharuddin, The Univ. of Memphis (United States); E. A. Essock, Univ. of Louisville (United States)

We propose a novel technique that exploits multi-fractal features for classifying glaucoma from ocular normal patients using retinal nerve fiber layer (RNFL) thickness measurement data. We apply a box-counting (BC) method, which utilizes pseudo 2D images from 1D RNFL data, and a multi-fractional Brownian motion (mBm) method, which incorporates both fractal and wavelet analyses, to analyze optical coherence tomography (OCT) data from 136 study participants (63 with glaucoma and 73 ocular normal patients). For statistical performance comparison, we compute the sensitivity, specificity and area under receiver operating curve (AUROC). The AUROCs in identifying glaucoma from ocular normal patients were 0.81 (BC), 0.87 (mBm), and 0.89 (BC+mBm), respectively.

7963-136, Poster Session

Feature-based glaucomatous progression prediction using scanning laser polarimetry data

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In this work, we investigate the effectiveness of a novel fractal feature-based technique in predicting glaucomatous progression using retinal nerve fiber layer (RNFL) thickness measurement data. The technique is used to analyze GDx variable corneal compensator (GDx-VCC) scanning laser polarimeter (SLP) data from one eye of 96 study participants (14 progressors, 45 non-progressors, and 37 ocular normal patients). The novel feature is obtained by using a 2D box counting (BC) method, which utilizes pseudo 2D images from 1D RNFL thickness measurement data. For statistical performance evaluation and comparison, we compute specificity and area under receiver operating curve (AUROC) for fractal analysis (FA) and other existing feature-based techniques such as fast-Fourier analysis (FFA) and wavelet-Fourier analysis (WFA). The AUROCs indicating discrimination between progressors and non-progressors using the classifiers with the selected FA, WFA, and FFA features are 0.82, 0.78 and 0.82 respectively for 6 months prior to progression. We then use the same classifiers to compute specificity in ocular normal patients. The corresponding specificities for ocular normal patients are 0.86, 0.76 and 0.86 for FFA, WFA and FA methods, respectively.

7963-137, Poster Session

An ensembling approach for optic cup detection based on spatial heuristic analysis in retinal fundus images

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Optic cup detection remains a challenging task in retinal image analysis, and is of particular importance for glaucoma evaluation, where disease severity is often assessed by the size of the optic cup. Various methods based on different image, regional and pixel features have previously been reported. The selection of the better performing method is often determined based on an overall evaluation metric. However, such a process tends to ignore the salient benefits each method can have in a particular region, although the method may not perform as well overall. In this paper, we propose an approach which aims to fuse the advantages of each method based on the specific performance in each defined sector, in order to generate an ensembled optic cup which is obtained from the optimal combination of the component methods. Segmentations from the component methods are first projected onto angles of interest originating from the optic disc centre. Subsequently, a Bayesian approach is adopted to analyze the segmentation results for each sector, and thereafter automatically select the optimal candidate result for that sector. The ensembled optic cup is formed from the results of all sectors. We conducted experiments on a sample data set of 71 retinal images. The results show that the ensemble approach performs better than the individual segmentations in the Dice (0.81) and Hausdorf (42.05) metrics, as well as a lower VCDR disparity (0.065) compared to the ground truth segmentation, and are promising for the continued development of such an approach.

7963-138, Poster Session

Automatic arteriovenous crossing phenomenon detection on retinal fundus images

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Arteriolosclerosis is one cause of acquired blindness. Retinal fundus image examination is useful for early detection of arteriolosclerosis. In order to diagnose the presence of arteriolosclerosis, the physicians find the silver-wire arteries, the copper-wire arteries and arteriovenous crossing phenomenon on retinal fundus images. The focus of this study was to develop the automated detection method of the arteriovenous crossing phenomenon on the retinal images. The blood vessel regions were detected by using a double ring filter, and the cross sections of artery and vein were detected by using a ring filter. The center of that ring was an interest point, and that point was determined as a cross section when there were over four blood vessel segments on that ring. And two blood vessels gone through on the ring were classified into artery and vein by using the pixel values on red and blue component image. Finally, V2-to-V1 ratio was measured for recognition of abnormalities. V1 was the venous diameter far from the blood vessel cross section, and V2 was the venous diameter near from the blood vessel cross section. The cross section with V2-to-V1 ratio over 0.8 was experimentally determined as abnormality. Twenty four images, including 27 abnormalities and 54 normal cross sections, were used for preliminary evaluation of the proposed method. The proposed method was detected 73% of cross sections when the 2.8 sections per image were mis-detected. And, 59% of abnormalities were detected by measurement of V1-to-V2 ratio when the 1.7 sections per image were mis-detected.

7963-139, Poster Session

Optic disk detection using vessel centerline detection on a directional match filter surface

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Optic Disk (OD) detection is an essential step in the automatic analysis of digital color fundus images. We present in this paper an automatic method to detect the OD position in the digital fundus images. The proposed method is an extension of the existing method with enhanced vessel segmentation algorithm, based on matching the blood vessel directions through directional match filter within the OD vicinity. Proposed method starts by normalizing the background of the image and enhancing the thin vessels by processing the image with the set of line detection filters in four different directions, results in improving the discrimination between the vessels and the background. Vessel segmentation method with enhanced performance is used which significantly effects the performance and efficiency of the proposed method. Vessels centerlines are detected by using directional information provided from a set of Directional Difference of offset Gaussian operators (DOOG) in all possible directions. Statistical region growing process is used to connect the candidate points obtained in the previous step. Consequently, Vessel direction map (VDM) is obtained implicitly in this process. The segmented vessels are filtered using a local intensity characteristic in order to reduce the OD candidates. The difference between predefine directional match filter (resized into six different sizes) and VDM is calculated and the result with the minimum difference provides an estimate of the OD centre. Enhancing the performance of the vessel segmentation algorithm has significantly effect the performance and efficiency of the proposed method. The proposed method is evaluated extensively on three publicly available DRIVE, STARE and DIARETDB0 databases. OD was successfully detected in all of the 40 images of DRIVE data base and all of 130 images in DIARETDB0 database while OD was detected correctly in 80 out of 81 images in STARE database.

7963-141, Poster Session

Dual angle scan protocol with Doppler optical coherence tomography for retinal blood flow measurement

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To improve the scan quality of Doppler Optical coherence tomography for blood flow measurement, we investigate how to improve the Doppler signal for all vessels around optic disc. Doppler signal is depending on the Doppler angle, which is defined as angle between OCT beams and normal direction vessel. In this examination, we test the effect of different OCT beam direction on Doppler angles of all veins. We also test maximizing the Doppler angle by combining scans with different OCT beams direction. Three criteria were used to evaluate the overall quality, average Doppler angle, the percentage of vessels with Doppler angle larger than the optimize value, the percentage of vessel with Coefficient variance of Doppler angle less than the optimize value. The result showed that the best protocol is to maximize the Doppler angle from one scan with OCT beam through supranasal portion of pupil and other scan with OCT beam through infranasal portion of pupil.

7963-143, Poster Session

Continuous measurements of mandibular cortical width on dental panoramic radiographs for computer-aided diagnosis of osteoporosis

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It has been reported that the inferior cortical width of the mandible is useful for identifying osteoporotic patients. The aim of this study is to develop a computer-aided osteoporosis diagnosis system that automatically determines the inferior cortical width of the mandible continuously on dental panoramic radiographs in order to realize statistically more robust measurements than the conventional one-point measurements. The cortical width was measured by enhancing the original image, determining cortical boundaries, and finally evaluating the distance between boundaries continuously throughout the region of interest. The diagnostic performance using the average width calculated from the continuous measurement was compared with BMD at lumbar spine and femoral neck in 100 postmenopausal women. We experimentally showed that the superiority of our method with improved sensitivity and specificity of 92.0 and 78.7%, respectively compared with lumbar spine BMD, 91.7 and 72.4%, respectively compared with femoral neck BMD in terms of efficacy for diagnosing osteoporosis, while our conventional one-point measurement below the mental foramen reported sensitivity and specificity of 88.0 and of 58.7% in the case of lumbar spine BMD and 87.5 and 56.3%, respectively in the case of femoral neck BMD. We also assessed that the diagnosis and classification of women with osteoporosis using support vector machine employing the average and variance of the continuous measurements gave excellent discrimination ability. It yields sensitivity and specificity of 90.9 and 83.8%, respectively with lumbar spine and 90.0 and 69.6%, respectively with femoral neck BMD. Performance comparison and simplicity of this method indicate that our computer-aided system is readily applicable to clinical practice.

7963-144, Poster Session

Multimodality segmentation of axillary lymph node (ALN) with live feedback

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Purpose: To develop a method for ALN segmentation across multiple modalities (US and MRI), incorporating live feedback.

Methods: A reliable segmentation method was developed to efficiently and interactively delineate the cortex and hilum of ALNs, and automatically measure significant features.

The user initiates the segmentation by selecting the center of the ALN, and a boundary pixel. The image is unwrapped around the center pixel and a directed graph is constructed. The Dijkstra's minimum cost path to the boundary pixel is computed for all pixels.

As the user moves the mouse around the image, the path to that pixel is displayed, giving live feedback for a possible segmentation (shown in yellow in Fig. 1). The user can select a pixel as a 'fixed' entry in the segmentation, finalizing the path from the previous 'fixed' point, and continuing from the new point. In this way, the user is able to override the default segmentation in regions that may be hard to identify, but they are not required to input every pixel. The average and std. deviation of ALN features were computed on both modalities using 13 ALNs, then 3 radiologists manually measured the same features.

Results: Table 1 shows the manual and computerized measurements average and st. deviation in mm.

There were no significant differences among the long axis, short axis, and MCT measurements between US and MRI-T2 weighted sequence ($P > 0.05$) for both manual and computerized measurements and between manual and computerized measurements on each modality.

New or breakthrough work to be presented: Multi-modality efficient and reliable segmentation and measurements computation applied to ALN on US and breast MR images.

Conclusion: Computerized multi-modality segmentation method with live feedback can help make ALN diagnosis more objective and efficient.

7963-145, Poster Session

Automated classification and visualization of healthy and pathological dental tissues based on near-infrared hyperspectral imaging

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Despite major improvements in dental healthcare and technology, dental caries remains one of the most prevalent chronic diseases of modern society. The initial stages of dental caries are characterized by demineralization of enamel crystals, commonly known as white spots which are difficult to diagnose. If detected early enough, such demineralization can be arrested and reversed by non-surgical means through well established dental treatments (fluoride therapy, anti-bacterial therapy, low intensity laser irradiation). Near-infrared (NIR) hyper-spectral imaging is a new promising technique for early detection of demineralization based on distinct spectral features of healthy and pathological dental tissues. In this study, we apply NIR hyper-spectral imaging to classify and visualize healthy and pathological dental tissues including enamel, dentin, calculus, dentin caries, enamel caries and demineralized areas. For this purpose, a standardized teeth database was constructed consisting of 12 extracted human teeth with different degrees of natural dental lesions imaged by NIR hyper-spectral system, X-ray and digital color camera. The color and X-ray images of teeth were presented to a clinical expert for localization and classification of the dental tissues, thereby obtaining the gold standard. Principal component analysis (PCA) was used for multivariate local modeling of healthy and pathological dental tissues. Finally, the dental tissues were classified by employing multiple discriminant analysis. High agreement was observed between the resulting classification and the gold standard with the sensitivity and specificity exceeding 84.2% and 96.6%, respectively. This study demonstrates that NIR hyper-spectral imaging has considerable potential for imaging dental tissues and diseases.

7963-146, Poster Session

A two-view ultrasound CAD system for spina bifida detection using Zernike features

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In this work, we address a very specific CAD (Computer Aided Detection/ Diagnosis) problem and try to detect one of the relatively common birth defects - spina bifida, in the prenatal period. To do this, fetal ultrasound images are used as the input imaging modality, which is the most convenient so far. Our approach is to decide using two particular types of views of the fetal neural tube. Transcerebellar head (i.e. brain) and transverse (axial) spine images are processed to extract features which are then used to classify healthy (normal), suspicious (probably defective) and non-decidable cases. Decisions raised by two independent classifiers may be individually treated, or if desired and if data related to both modalities are available, those decisions can be fused to keep matters more secure. Even more security can be attained by using more than two modalities and base the final decision on all those potential classifiers.

Our current system relies on feature extraction from images for cases (for particular patients). The first step is image preprocessing and segmentation to get rid of useless image pixels and represent the input in a more compact domain, hopefully being more representative for good classification performance. Next, a particular type of feature extraction, which uses Zernike moments computed on either B/W or gray-scale image segments, is performed. The aim here is to obtain values for indicative markers that signal the presence of spina bifida. Markers differ depending on the image modality being used. Either shape or texture information captured by moments may propose useful features. Finally, SVM is used to train classifiers to be used as decision makers. Our experimental results show that a promising CAD system can be actualized for the specific purpose. On the other hand, the performance of such a system would highly depend on the qualities of image preprocessing, segmentation, feature extraction and comprehensiveness of image data.

7963-147, Poster Session

Automatic measurement of early gestational sac diameters from one scan session

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Gestational sac (Gs) diameters are commonly measured by routine ultrasound in early pregnancy. However, manually searching for the standardized plane of Gs and measuring the diameters are time-consuming for sonographers. In this paper, we develop a three-stage automatic solution for this procedure, namely, Gs detection based on AdaBoost, Gs standardized plane indexing based on knowledge and Gs measurement by mean-shift filter and spectral segmentation. In order to precisely and efficiently locate the position of Gs in each frame, a coarse to fine Gs detection scheme based on AdaBoost algorithm is explored. Then, a very simple, yet robust method that compare the distance between adjacent center points of the detected objects is introduced, this procedure can greatly reduce the false alarms generated by the above detection process and provide more reliable indexing results. Finally, a mean-shift filtering is applied to the indexed Gs location to eliminate noise, and then a spectral segmentation combined with region merging is utilized to separate Gs region from the background for further diameters measurement. Experiments on over 3,000 images and the results achieve nearly 88% detection rate and less than 2% false alarm rate. Further experiments carried out on 31 videos show that by using the proposed methods, the number of indexed error is only 1 and the average measurement error is 0.059 for the length diameters and 0.083 for the width diameters. The proposed approach is proved to have potential benefit for clinical applications.

7963-43, Session 9

Texture feature selection with relevance learning to classify interstitial lung disease patterns

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The Generalized Matrix Learning Vector Quantization (GMLVQ) is used to estimate the relevance of texture features in their ability to classify interstitial lung disease patterns in high-resolution computed tomography (HRCT) images.

After a stochastic gradient descent, the GMLVQ algorithm provides a discriminative distance measure of relevance factors, which can account for pairwise correlations between different texture features and their importance for the classification of healthy and diseased patterns.

Texture features were extracted from gray-level co-occurrence matrices (GLCMs), and were ranked and selected according to their relevance obtained by GMLVQ and, for comparison, to a mutual information (MI) criteria.

A k-nearest-neighbor (kNN) classifier and a Support Vector Machine with a radial basis function kernel (SVMrbf) were optimized in a 10-fold cross-validation for different texture feature sets.

In our experiment with real-world data, the feature sets selected by the GMLVQ approach had a significantly better classification performance compared with feature sets selected by a MI ranking.

7963-44, Session 9

A robust independent component analysis (ICA) model for functional magnetic resonance imaging (fMRI) data

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Carefully designed experiments coupled with proper analysis of functional magnetic resonance imaging (fMRI) data provides us with a powerful as well as noninvasive tool for understanding of cognitive processes associated with specific brain regions and hence could be used for detecting abnormalities induced by a diseased state. Hypothesis-driven General Linear Model (GLM) and data-driven Independent Component Analysis (ICA) model are the two most commonly used models for fMRI data analysis. A hybrid-ICA-GLM model combines two models together to take advantages of benefits from both models for more accurate mapping of the task-induced activated brain regions. However, the conventional ICA model is a noise-free model that leads to source components that are often difficult to interpret. A probabilistic ICA model has been recently introduced for identification of truly independent source components. We propose a modified hybrid-ICA-GLM model with probabilistic ICA that includes a noise model. In this modified hybrid model, a probabilistic principle component analysis (PPCA)-based model order estimation is used in the ICA stage to extract the intrinsic number of original time courses. In addition, frequency matching is introduced into the time course selection stage, along with temporal correlation, regression model F-test, and reference function re-projection, to produce a more accurate design matrix for GLM. A standard fMRI dataset is used to compare the results of applying GLM and the proposed hybrid ICA-GLM to generate activation maps. The proposed hybrid-ICA-GLM model fits the data better with higher z-score and reveals more meaningful activated regions.

7963-45, Session 9

Manifold learning for dimensionality reduction and clustering of skin spectroscopy data

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Diagnosis of benign and malign skin lesions is currently done mostly relying on visual assessment and frequent biopsies performed by dermatologists. As the timely and correct diagnosis of these skin lesions is one of the most important factors in the therapeutic outcome, leveraging new technologies to assist the dermatologist seems natural. Optical spectroscopy is a technology that is being established to aid skin lesion diagnosis, as the multi-spectral nature of this imaging method allows to detect multiple physiological changes like those associated with increased vasculature, cellular structure, oxygen consumption or edema in tumors. However, spectroscopy data is typically very high dimensional (on the order of thousands), which causes difficulties in visualization and classification. In this work we apply different manifold learning techniques to reduce the dimensions of the input data and get clustering results. Spectroscopic data of 48 patients with suspicious and actually malignant lesions was analyzed using ISOMAP, Laplacian Eigenmaps and Diffusion Maps with varying parameters and compared to results using PCA. Using optimal parameters, both ISOMAP and Laplacian Eigenmaps could cluster the data into suspicious and malignant with 97% accuracy, compared to the diagnosis of the treating physicians.

7963-46, Session 9

A cost constrained boosting algorithm for fast lesion detection and segmentation

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Machine learning techniques like point wise classification are widely used for object detection and segmentation. However, for big search spaces like CT images, this approach becomes computationally very demanding. Designing strong yet compact classifiers is thus of great importance for systems that ought to be clinically used as time is a limiting factor in clinical routine. The runtime of a system plays an important role in the decision about its application.

In this paper we propose a technique for reducing the computational complexity of voxel classification systems based on the well-known AdaBoost algorithm in general and Probabilistic Boosting Trees in particular.

We describe a means of incorporating a measure of hypothesis complexity into the optimization process, resulting in classifiers with lower evaluation cost. More specifically, in our approach the hypothesis generation that is performed during the AdaBoost training is no longer based only on the error of a hypothesis but also on its complexity. This leads to a reduced overall classifier complexity and thus shorter evaluation times.

The validity of the approach is shown in an experimental evaluation. In a cross validation experiment, a system for automatic segmentation of liver tumors in CT images, that is based on the Probabilistic Boosting Tree, was trained with and without the proposed extension. By using the methods described here the evaluation cost for classifying previously unseen samples could be reduced by 83% without losing classification accuracy.

7963-47, Session 9

Balancing the training dataset using convex skin

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Conventional SVM algorithms require that the entire dataset be available at the time of training a classifier. While a large number of training examples helps to reduce the generalization error, the learning process can become computationally expensive. For instance, medical data are collected and stored over long periods. The cumulative data sets become overly large. Out of the data collected, only a small fraction is positive, which would suggests an imbalanced dataset. In such situations incremental learning data is to be processed in parts, and the results are combined to make it feasible to use with current computational resources. In this paper a novel method to find the skin of the convex hull in the feature space is presented. The intuition is that only the samples within the skin are retained in training. This ensures that the informative samples which could become support vectors due to rotation of the decision boundary are retained for the incremental steps. When additional samples are provided, they will be used together with the skin of the convex hull constructed from previous dataset. Therefore, much less number of instances is used in training process. Our experiments on the UCI datasets and CE videos show the classification performance increases asymptotically, as more samples are seen.

7963-48, Session 10

Probabilistic method for context-sensitive detection of polyps in CT colonography

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Radiologists can outperform computer-aided detection (CAD) systems for CT colonography, because they consider not only the local features but also the context of suspicious findings. In particular, isolated findings are considered as more suspicious than clustered ones. We developed a computational method for modeling this problem-solving technique in the reduction of false-positive (FP) CAD detections in CT colonography. First, conventional CAD was used to detect polyp candidates from CT colonography data, and a Bayesian neural network was used to estimate the likelihood that a polyp candidate represents a true lesion. Next, context features were calculated to characterize the distribution and polyp likelihood of polyp candidates in local neighborhood regions of each polyp candidate. The values of the context features were assigned to a belief network that modulated the detection sensitivity to detect isolated polyp candidates at a higher sensitivity than clustered ones. The detection performances of the context-sensitive CAD and a conventional CAD were compared by use of leave-one-patient-out evaluation with 73 patients and 107 colonoscopy-confirmed lesions. For lesions 6 - 9 mm (n=45), conventional CAD detected 82% of the lesions with a median of 6 false positives per CT scan, whereas context-sensitive CAD detected these lesions with a median of 4 false positives. The increment in area under free-response operating characteristic curve (AUC) with the context-sensitive CAD was statistically significant ($p<0.05$). For lesions >10 mm (n=62), the detection sensitivity was 98% but the increment in AUC was not significant.

7963-49, Session 10

Detection of longitudinal ulcer using roughness value for computer aided diagnosis of Crohn's disease

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The purpose of this paper is to present a new method to detect longitudinal ulcers, which is one of the symptoms of Crohn's disease, from CT images. Crohn's disease is an inflammatory disease of the digestive tract. Crohn's disease commonly affects the small intestine. An optical or a capsule endoscope is used for small intestine examinations. However, these endoscopes cannot pass through intestinal stenosis parts in some cases. A CT image based diagnosis allows a physician to observe whole intestine irrespective of intestinal stenosis parts. However, because of the complicated shape of the large and the small intestines, understanding of shapes of the intestine and lesion positions are difficult in the CT image based diagnosis. Computer aided diagnosis system for Crohn's disease having automated lesion detection is required for efficient diagnosis. We propose a method to detect longitudinal ulcers from CT images. Longitudinal ulcers make rough surface of the large and small intestinal wall. The rough surface consists of combination of convex and concave parts on the intestinal wall. We detect convex and concave parts on the intestinal wall by a blob and an inverse-blob structure enhancement filters. A lot of convex and concave parts concentrate on roughed parts. We introduce a roughness value to differentiate convex and concave parts concentrated on the roughed parts from the other on the intestinal wall. The roughness value effectively reduces false positives of longitudinal ulcer detection. Experimental results showed that the proposed method can detect convex and concave parts on the longitudinal ulcers.

7963-50, Session 10

3D supine and prone colon registration for computed tomographic colonography scans based on graph matching

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In this paper, we propose a new registration method for supine and prone computed tomographic colonography scans based on graph matching. We first formulated 3D colon registration as a graph matching problem. Then we utilized a graph matching algorithm based on mean field theory. During the iterative optimization process, one-to-one matching constraints were added to the system step-by-step. Prominent matching pairs found in previous iterations are used to guide subsequent the mean field calculation. The advantage of the proposed method is that it does not require a colon centerline for registration. We tested the algorithm on a CTC dataset of 19 patients with 19 polyps. The average registration error of the proposed method was 4.0cm (std. 2.1cm). The 95% confidence intervals were [3.0cm, 5.0mm]. There was no significant difference between the proposed method and our previous method based on the normalized distance along the colon centerline ($p=0.1$).

7963-51, Session 10

Computer-aided teniae coli detection using height maps from computed tomographic colonography images

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CT colonography is a minimally invasive technique for polyps and cancer screening. Teniae coli are important anatomical landmarks on human colon. This paper proposes a novel method for teniae coli detection on CT colonography. We first unfold the 3D colon using a reversible projection technique and compute the 2D height map of the unfolded colon. The teniae are detected using the height map and then reversely

projected back to 3D. Since teniae are located where the haustral folds meet, we break down the problem by first detecting the folds. We apply 2D Gabor filter banks to extract fold features. The maximum response of the filter banks is selected as the feature image. The fold centers are then identified using piecewise thresholding on the feature image. Connecting the fold centers yields a path of the folds. Teniae coli are finally extracted as lines between the fold paths. Experimental results are promising with an average normalized RMSE of 5.66% and standard deviation of 4.79%.

7963-52, Session 10

Temporal volume flow: an approach to tracking failure recovery

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The simultaneous use of pre-segmented virtual and optical colonoscopy images during routine endoscopic procedures provides useful clinical information to the gastroenterologist. Blurry images in the video stream can cause the tracking system to fail, when the endoscope touches a wall or a polyp. The ability to recover from such failures is critical to building a robust tracking system, and involves identifying similar images before and after the blurry sequence.

We propose a temporal volume flow approach to recover from tracking failures. Our method employs nonlinear intensity and gradient constancy models, as well as a discontinuity-preserving smoothness constraint to formulate an energy function; minimizing this function between two temporal volumes before and after the blurry sequence results in an estimate of temporal volume flow. A voting approach is then used to search for an image pair with the maximum number of point correspondences. A region flow algorithm is used to recover motion parameters.

We applied our algorithm to three optical colonoscopy sequences. The first sequence, with 235 images in the ascending colon, had 12 blurry images. The temporal volume flow approach was more accurate than the region flow approach, which resulted in a significant rotation error. Similar results were observed in the second patient in the descending colon, containing 535 frames and 24 blurry frames. The third sequence contained 580 images in the descending colon with 172 blurry images. The region flow method failed in this case, while temporal volume flow method was able to recover from the blurry sequence.

7963-53, Session 10

On-the-fly detection of images with gastritis aspects in magnetically-guided capsule endoscopy

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Capsule Endoscopy (CE) was introduced in 2000 and has since become an established diagnostic procedure for the small bowel, colon and esophagus. For the CE examination the patient swallows the capsule, which then travels through the GI tract under the influence of peristaltic movements. CE is not indicated for stomach examination, as the capsule movements cannot be controlled from the outside and the entire surface of the stomach cannot be reliably covered. Magnetically-guided capsule endoscopy (MGCE) was introduced in 2010. For the MGCE procedure the stomach is filled with water and the capsule is navigated from the outside using an external magnetic field. During the examination the operator can control the motion of the capsule in order to obtain a sufficient number of stomach surface images with diagnostic value. The quality of the examination depends on the skill of the operator and his ability to detect aspects of interest in real time. We present a novel computer-assisted diagnostic-procedure algorithm for indicating gastritis pathologies in the stomach during the examination. It is based on pre-processing methods and feature vectors that are suitably chosen for the challenges of the MGCE imaging (suspended particles, bubbles, lighting). An image is classified using an ADA-boost trained classifier. For the classifier training, a number of possible features were investigated. Statistical evaluation was conducted to identify relevant features with discriminative potential. The proposed algorithm was tested on 12 video sequences stemming from 6 volunteers. A mean detection rate of 84% was achieved during leave-one out cross-validation.

7963-54, Session 11

Multiscale quantification of tissue spiculation and distortion for detection of architectural distortion and spiculated mass in mammography

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This paper proposes a multiscale method to quantify tissue spiculation and distortion in mammography CAD systems that aims at improving the sensitivity in detecting architectural distortion (AD) and spiculated mass (SM). This approach addresses the difficulty of predetermining the neighborhood size for feature extraction in characterizing lesions demonstrating SM/AD that may appear in different sizes. The quantification is based on the recognition of tissue spiculation and distortion pattern using multiscale first-order phase portrait model (PPM) in texture orientation field generated by Gabor filter bank (GFB). A feature map is generated under each PPM scale. Feature maps generated under different PPM scales are then combined to generate a final feature map for each mammogram that quantifies the recognition of both standard and distorted spiculation pattern in different sizes. Two features are then extracted from the feature map. These two features will be combined with other mass features to provide enhanced discriminate ability in detecting lesions demonstrating SM/AD. The efficiency and efficacy of the proposed method are demonstrated with results obtained by applying the method to over 500 cancer cases and over 1000 normal cases.

7963-55, Session 11

Computer aided detection of breast masses in mammography using support vector machine classification

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The reduction of false positive marks in breast mass CAD is an active area of research. Typically, the problem can be approached by either developing more discriminative features or by employing different classifier designs. Usually one intends to find an optimal combination of classifier configuration and small number of features to ensure high classification performance and a robust model with good generalization capabilities.

In this paper, we investigate the potential benefit of relying on a support vector machine (SVM) for the detection of malignant masses. The evaluation is based on a 10-fold cross validation over a large database of more than 10000 screen film mammograms. We assess the SVM performance compared to a neural network (NN) as well as k-nearest neighbors and linear discriminant analysis. For description of detected mass candidates we use a set of 30 resp. 73 image region features. The CAD performance is quantified by the mean exam sensitivity in 0.05 to 1

false positives per normal image on the free-response receiver operating characteristic curve.

Our results indicate a superior performance of the SVM classifier over the alternative schemes. In particular, and in contrast to a state of the art NN, the SVM proved to further benefit from using the full set of 73 region features.

7963-56, Session 11

Computerized prediction of breast cancer risk: comparison between the global and local bilateral mammographic tissue asymmetry

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We developed and preliminarily tested a new breast cancer risk prediction model based on computerized bilateral mammographic tissue asymmetry. In this study, we investigated and compared the performance difference of our risk prediction model when the bilateral mammographic tissue asymmetrical features were extracted in three different methods namely (1) the entire breast area, (2) the adaptively selected regions of interest (ROIs), and (3) the mirror-matched local strips. A testing dataset including 100 negative and 100 positive cases for having or developing breast abnormalities or cancer was selected from a large and diverse full-field digital mammography (FFDM) image database. To detect bilateral mammographic tissue asymmetry, two sets of 20 initial "global" features were extracted from the entire breast areas and ROIs of two bilateral mammograms in craniocaudal view and their differences were computed. Meanwhile, a pool of 16 local histogram-based statistic features was computed from eight mirror-matched strips between the left and right breast. Using genetic algorithm (GA) to select optimal features, three artificial neural networks (ANN) were built to predict the risk of a test case developing cancer. Using the leave-one-case-out testing method, three GA-optimized ANNs yielded the areas under receiver operating characteristic (ROC) curves of 0.754±0.024 (entire breast area), 0.690±0.026 (selected ROI), and 0.726±0.026 (8 pairs of local strips), respectively. The risk prediction model is able to detect 71.4% of cancer cases 6 to 18 months earlier at 80% specificity level. This study compared three methods to compute bilateral mammographic tissue asymmetry and demonstrated that bilateral mammographic tissue asymmetry was a useful breast cancer risk indicator with high discriminatory power.

7963-57, Session 11

A comparison study of textural features between FFDM and film mammogram images

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With the introduction of full-field digital mammography (FFDM) in recent years, there has been interest in comparing the performance of computer-aided diagnosis (CAD) algorithms when applied to film versus FFDM mammograms, and some existing CAD algorithms have been shown to yield similar performance on both types of images. In this work, we conducted an imaging study to make a direct, quantitative comparison of image features measured by film and FFDM. We acquired images of cadaveric breast specimens containing simulated microcalcifications using both a GE digital mammography system and a screen-film system (with subsequent digitization). The use of cadaveric specimens is to achieve anatomically realistic backgrounds, and is ideal for our purposes, since it permits perfect registration between film and FFDM images, thereby allowing meaningful quantitative comparisons. In addition, it permits multiple images to be acquired, which is not usually possible for live subjects. To quantify the image features of both film and FFDM, we calculated a set of 12 texture features derived from spatial gray-level dependence (SGLD) matrices. These features were previously used in CAD for characterizing tissue regions containing clustered microcalcifications in mammograms. Our results demonstrate that there is a great degree of agreement between film and FFDM, with the correlation coefficient of the feature vector (formed by the 12 textural features) being as high as 0.9597 between the two. These results indicate that textural features may be interchangeable between film and FFDM for CAD algorithms.

7963-58, Session 11

Mammographic parenchymal texture as an imaging marker of hormonal activity: a comparative study between pre- and post-menopausal women

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Mammographic parenchymal texture patterns have been previously shown to be related to breast cancer risk. Yet, little is known about the biological basis underlying this association. Here, we investigate the potential of mammographic parenchymal texture patterns to be serving as an inherent phenotypic imaging marker of endogenous hormonal exposure of the breast tissue. CC and MLO digital mammographic (DM) images of the unaffected breasts from 138 women with unilateral breast cancer were retrospectively analyzed. Menopause status was used as a surrogate marker of endogenous hormonal activity. Retroareolar 2.5cm2 ROIs were segmented from post-processed images using an automated algorithm. Parenchymal texture features of skewness, coarseness, contrast, energy, homogeneity, grey-level spatial correlation, and fractal dimension were computed. Receiver operating characteristic (ROC) curve analysis was performed to evaluate feature classification performance in distinguishing between 72 pre- and 66 post-menopausal women. A logistic regression model was constructed to assess the effect of each of the texture features to independently predict menopause status. ROC analysis showed that texture features have inherent capacity to distinguish between pre- and post-menopausal statuses ($AUC>0.5$, $p<0.05$). Logistic regression that included all texture features yielded an ROC curve with an AUC of 0.76. Addition of age at menarche, ethnicity, contraception use and estrogen therapy use lead to a modest improvement to the model ($AUC=0.78$) while texture features maintained significant contribution ($p<0.05$). Differences in parenchymal texture features between pre- and post- menopausal women suggest that mammographic texture patterns could have the potential to serve as a surrogate imaging marker of endogenous hormonal activity.

7963-59, Session 12

Classification of pulmonary emphysema from chest CT scans using integral geometry descriptors

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To gain insight into the underlying pathways of emphysema and monitor the effect of treatment, methods to quantify and phenotype the different types of emphysema from chest CT scans are of crucial importance. Current standard measures rely on density thresholds for individual voxels, which is influenced by inspiration level and does not take into account the spatial relationship between voxels. Measures based on texture analysis do take the interrelation between voxels into account and therefore might be useful for distinguishing different types of emphysema. In this study, we propose to use Minkowski functionals combined with rotation invariant Gaussian features to distinguish between healthy and emphysematous tissue and classify three different types of emphysema.

Minkowski functionals characterize binary images in terms of geometry and topology. In 3D, four Minkowski functionals are defined. By varying the threshold and size of neighborhood around a voxel, a set of Minkowski functionals can be defined for each voxel. Ten chest CT scans with 1810 annotated regions were used to train the method. A set of 74 features was calculated for each training sample from which 10 features were selected to be most informative. A linear discriminant classifier was trained to classify each voxel in the lungs into a subtype of emphysema or normal lung. The method was applied to an independent test set of 30 chest CT scans with varying amounts and types of emphysema with 4347 annotated regions of interest. The method is shown to perform well, with an overall accuracy of 95%.

7963-60, Session 12

Lung partitioning for x-ray CAD applications

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Partitioning the lung into multiple regions becomes a crucial step in any CAD application based on PA chest X-ray. The clavicle and ribs occupy major space inside the lung as seen in the chest x-ray PA image. Segmenting each of these organs and partitioning the lung into homogeneous regions forms a crucial step in any CAD application to better classify the abnormalities. In this paper we present two separate algorithms to segment ribs and the clavicle bone in a completely automated way. The rib segmentation algorithm uses phase congruency and the clavicle detection algorithm uses Mean curvature followed by Radon transform. Both the algorithms work on the premise that the presentation of each of these anatomical organs inside the left and right lung has a specific orientation range within which they are confined to. The search space for both the algorithms is limited to the region inside the lung, which is obtained by an automated lung segmentation algorithm that was developed in our group. Both the algorithms were tested on 100 images on patients affected with Pneumoconiosis and the results are promising.

7963-61, Session 12

Estimating local scaling properties for the classification of interstitial lung disease patterns

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Local scaling properties of texture regions were compared in their ability to classify morphological patterns known as 'honeycombing' that are considered indicative for the presence of fibrotic interstitial lung diseases in high-resolution computed tomography (HRCT) images.

For 14 patients with known occurrence of honey-combing, a stack of 70 axial, lung kernel reconstructed images were acquired from HRCT chest exams.

241 regions of interest of both healthy and pathological (89) lung tissue were identified by an experienced radiologist.

Texture features were extracted using six properties calculated from gray-level co-occurrence matrices (GLCM), Minkowski Dimensions (MDs), and the estimation of local scaling properties with Scaling Index Method (SIM).

A k-nearest-neighbor (k-NN) classifier and a Multilayer Radial Basis Functions Network (RBFN) were optimized in a 10-fold cross-validation for each texture vector, and the classification accuracy was calculated on independent test sets as a quantitative measure of automated tissue characterization.

A Wilcoxon signed-rank test was used to compare two accuracy distributions including the Bonferroni correction.

The best classification results were obtained by the set of SIM feature, which performed significantly better than all the standard GLCM and MD features ($p<0.005$) for both classifiers with the highest accuracy (94.1%, 93.7%; for the k-NN and RBFN classifier, respectively).

The best standard texture features were the GLCM features 'homogeneity' (91.8%, 87.2%) and 'absolute value' (90.2%, 88.5%).

The results indicate that advanced texture features using local scaling properties can provide superior classification performance in computer-assisted diagnosis of interstitial lung diseases when compared to standard texture analysis methods.

7963-62, Session 12

High-throughput morphometric analysis of pulmonary airways in MSCT via a mixed 3D/2D approach

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Asthma and COPD are complex airway diseases with an increased incidence estimated for the next decade. Today, the mechanisms and relationships between airway structure/physiology and the clinical phenotype and genotype are not completely understood. We thus lack the tools to predict disease progression or therapeutic responses. One of the main causes is our limited ability to assess the complexity of airway diseases in large populations of patients with appropriate controls. Multi-slice computed tomography (MSCT) imaging opened the way to the non-invasive assessment of airway physiology and structure but the use of such technology in large cohorts requires a high degree of automation of the measurements. This paper develops an investigation framework and the associated image quantification tools for high-throughput analysis of airways in MSCT. A mixed approach is proposed, combining 3D and cross-section measurements of the airway tree where the user-interaction is limited to the choice of the desired analysis patterns. Such approach relies on the fully-automated segmentation of the 3D airway tree, calibre estimation and visualization based on morphologic granulometry, central axis computation and tree segment selection, cross-section morphometry of airway lumen and wall, and bronchus longitudinal shape analysis for stenosis/bronciectasis detection and measure validation. The developed methodology has been successfully applied to a cohort of 96 patients from a multi-center clinical study of asthma control in moderate and persistent asthma.

7963-63, Session 12

Interactive lung lobe segmentation and correction in tomographic images

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Lobe-based quantification of tomographic images is of increasing interest in lung diagnosis, monitoring, and treatment planning. With modern tomography scanners providing data sets with hundreds of slices, manual segmentation is time-consuming and not feasible in clinical routine. Especially for patients with severe lung pathology that are of particular clinical importance, automatic segmentation approaches frequently generate partially inaccurate or even completely unacceptable results.

In this work we present a modality-independent, semi-automated method that can be used both for generic correction of any existing lung lobe

segmentation and for segmentation from scratch. Intuitive slice-based drawing of fissure parts is used to introduce user knowledge.

Internally, the current fissure segmentation is represented by sampling points in 3D space that are interpolated to a fissure surface. Using morphological processing, a 3D impact region is computed for each user-drawn 2D curve. Based on the curve and impact region, the updated lobar boundary surface is immediately computed after each interaction step to provide instant user feedback.

The method was evaluated on 25 normal dose CT scans with a reference standard provided by a human observer. When segmenting from scratch, the mean distance to the reference fissure was 1.6 mm using an average of five interactions that corresponded to 50 seconds of interaction time per case. When correcting inadequate automatic segmentations, their mean distance to the reference could be reduced from 13.9 to 1.9 mm with comparable efforts. The evaluation shows that both correction of a given segmentation and segmentation from scratch can be successfully performed with few interactions in a short time.

7963-64, Session 12

Enhancing image classification models with multimodal biomarkers

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Frequently, computer-aided diagnosis systems (CADs) and image classification models simply analyze medical images to diagnose, quantify, and monitor the progression of a particular disease. However, patients often have a large number of studies done in conjunction with the acquisition of medical images that can be used to better assess the health conditions of a patient. For instance, blood results, electrocardiograms and pulmonary function tests are some of the analysis often performed on patients during the diagnosis process. Data fusion and integration of lab results with quantifiable image analysis present a unique opportunity to increase the accuracy of computer-assisted radiologic diagnosis.

In this paper, we present how highly correlated multi-modal features can be treated as biomarkers and how they can be used to enhance automatic image classification models. In particular, we show how blood and EKG features can be used to enhance the automatic scoring of subjects with pulmonary fibrosis. Overall, a 3-5% improvement in accuracy was observed when CADs with multi-modal biomarkers were employed over CADs that only used image features to automatically score patients of pulmonary fibrosis. Our results show that lab values such as Erythrocyte Sedimentation Rate and Fibrinogen, as well as EKG measurements such as QRS and I:40, are statistically significant and can provide insights about the severity of the pulmonary fibrosis disease.

Conference 7964: Visualization, Image-Guided Procedures, and Modeling

Sunday-Tuesday 13-15 February 2011 • Part of Proceedings of SPIE Vol. 7964
Medical Imaging 2011: Visualization, Image-Guided Procedures, and Modeling

7964-01, Session 1

The use of virtual fiducials in image-guided kidney surgery

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The alignment of image-space to physical-space lies at the heart of all image-guided procedures. In intracranial surgery, point-based registrations can be used with either skin-affixed or bone-implanted extrinsic objects called fiducial markers. The advantages of point-based registration techniques is that they are robust, fast and have well developed mathematical foundation for the assessment of registration quality. In abdominal image-guided procedures such techniques have not be successful. It is difficult to accurately locate sufficient homologous intrinsic points in image-space and physical space and the implantation of extrinsic fiducial markers would constitute “surgery before the surgery.” Therefore image-space to physical-space registration for abdominal organs has been dominated by surface-based registration techniques which are iterative, prone to local minima, sensitive to initial pose and sensitive to percentage coverage of the physical surface.

In our work in image-guided kidney surgery we have developed a composite approach using “virtual fiducials”. In an open kidney surgery, the perirenal fat is removed and the surface of the kidney is dotted using a surgical marker. A laser range scanner (LRS) is used to obtain a surface representation and matching high definition photograph. A surface to surface registration is performed using a modified iterative closest point (ICP) algorithm. The dots are segmented from the high definition image and assigned the three dimensional values from the LRS pixels over which they lie. Then as the surgery proceeds we can use point-based registrations to re-register the spaces and track deformations due to vascular clamping and surgical tractions.

7964-02, Session 1

Surgical phantom for off-pump mitral valve replacement

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Off-pump, intracardiac, beating heart surgery has the potential to improve patient outcomes by eliminating the need for cardiopulmonary bypass and aortic cross clamping but it requires extensive image guidance as well as the development of specialized instrumentation. Previously, developments in image guidance and instrumentation were validated on either a static phantom or in vivo through porcine models. This paper describes the design and development of a surgical phantom for simulating off-pump mitral valve replacement inside the closed beating heart. The phantom allows surgical access to the mitral annulus while mimicking the pressure inside the beating heart. An image guidance system using tracked ultrasound, magnetic instrument tracking and preoperative models previously developed for off-pump mitral valve replacement is applied to the phantom. Pressure measurements and ultrasound images confirm the phantom closely mimics conditions inside the beating heart.

7964-03, Session 1

Deformable registration for cone-beam CT-guided surgery: modified Demons for excised tissue

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The ability to perform fast, accurate, deformable registration of preoperative images to intraoperative cone-beam CT (CBCT) images featuring surgical excisions was investigated for use in guidance of head and neck surgery. Existing deformable registration methods generally fail to account for tissue excised between image acquisitions and typically simply “move” voxels within the images. We have thus developed an approach in which an extra pseudo-spatial dimension is added during the registration process to act as sink of voxels which have been removed during the course of the procedure. A series of cadaveric images acquired using a prototype CBCT-capable C-arm were used to model tissue deformation and excision occurring during a surgical procedure, and the ability of deformable registration to correctly account for anatomical changes under these conditions was investigated. Using a previously developed version of the Demons deformable registration algorithm, we identify the difficulties that traditional registration algorithms encounter when faced with excised tissue and present a modified version of the algorithm better suited for use in intraoperative image-guided procedures. Studies were performed under varying degrees of deformation and tissue excision, and registration performance was quantified in terms of the ability to accurately account for tissue excision while avoiding spurious deformations arising around the excision.

7964-04, Session 1

Evaluation of an ad hoc model of detection physics for navigated beta-probe surface imaging

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Intraoperative surface imaging with navigated betaprobes has been shown to be a possibility to enable control of tumor resection borders. By employing ad hoc models of the detection physics the image quality can be improved. Our model computes the amount of radiation from a single point source that reaches the detector, with the solid angle subtended by the detector on the source, assuming perfect shielding. The sensitivity of the detector to the source due to the angle between the detector axis and the source-to-detector vector is also considered. A set of experiments was performed with three sources (two 10×10 mm2 and one 20×10 mm2 pieces of cellulose saturated with FDG) on a plate as phantom. Five sets of measurements were taken, three of them at a distance of 10mm from the plate und two at 30mm. At both distances one measurement set was taken in a random manner and the other ones systematically covering the whole area. The same experiments were simulated with our model and the GATE simulation framework. The resulting measurements from the experiments and simulations were then used to perform a reconstruction of the sources. The real measurements were compared to those simulated with our model and GATE, with a mean NCC of 80.64% for our model and 70.14% for

GATE. In the reconstructions of the real measurements the sources were visually quite well separated, however the reconstructions of the measurements simulated by the model show that there is still room for further improvement.

7964-05, Session 1

Computer assisted intervention surgery planning and navigation for percutaneous microwave ablation of lung cancer

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Microwave ablation is a promising option in lung cancer therapy. However, it's rarely used in percutaneous lung cancer therapy compared to liver cancer, because the presence of a large amount of air within the lung creates significant back shadowing artifacts that preclude adequate delineation of anatomic details on sonography. To utilize microwave ablation in malignant lung tumor therapy, we developed a novel percutaneous intervention surgery navigation system (CANIS-I), which capitalizes on using computer assisted technology to help lung cancer patients whose condition are not amenable to surgical resection, sonographic guidance and intraoperative CT surgery. In these surgeries, preoperative CT images with patient respiration state are first acquired, which are then visualized using GPU-accelerated volume rendering. The optimal surgery trajectories are then planned based on 3D thermal field computation and surgery simulation in the surgery planning software. During the surgery, the patient breath is control by a portable volume ventilator system which could limit the movement and displacement of the tumor. Then the microwave probe is punctured into the tumor according to the dynamic respiratory state and the tumor is ablated by microwave energy. After the surgery, postoperative CT are acquired and compared to the preoperative CT, and the surgery is evaluated by compare preoperative and postoperative CT images. The development of this technique represented a significant advance from the traditional ways for lung cancer therapy and significantly extends the indications of microwave ablation.

7964-06, Session 2

Engineering solutions in the operating room: a surgeon's perspective

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The past 2 decades have seen an explosion in engineering and technology solutions to reduce the invasiveness and risks of surgery. While the promise of genomic biology and 'personalized' medicine may revolutionize disease care and diagnosis in the coming decades, the operating room continues to offer a fertile ground for innovation.

Engineering solutions such as image-guided surgery (IGS), robotics, functional and tumor targeted imaging, and tissue ablation hold promise to potentially revolutionize surgery and improve patient outcomes. Key to the development of successful solutions is a close collaboration between development engineers and surgeons. While surgical training has typically stressed biologic and anatomic knowledge, basic knowledge of engineering concepts is becoming increasingly important for successful application of engineered solutions for patient safety and improved outcomes.

Utilizing a trans-institutional collaboration of engineers and surgeons, solutions such as incorporation of IGS into robotic and kidney surgery, advanced robotic and ablative technologies, and new imaging modalities are being explored at our institution and will be reviewed.

A variety of challenges and needs for advanced engineering solutions remain in the operative environment and will be discussed.

7964-07, Session 2

2D and 3D visualization methods of endoscopic panoramic bladder images

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While several mosaicking algorithms have been developed to compose endoscopic images of the internal urinary bladder wall into panoramic images, the quantitative evaluation of these output images in terms of visual distortions have often not been discussed. However, the visualization of the distortion level is highly desired for an objective image-based medical diagnosis. Thus, we present in this paper a method to create quality maps from the characteristics of transformation parameters, which were applied to the endoscopic images during the registration process of the mosaicking algorithm. For a global first view impression, the quality maps are laid over the panoramic image and highlight image regions in pseudo-colors according to their local distortions. This illustration supports then surgeons to identify visually distorted structures easily in the panoramic image, which have to be considered for objective medical interpretations. Aside from introducing quality maps in 2-D, we also discuss a visualization method to map panoramic images onto a 3-D spherical bladder model. Reference points are manually selected by the surgeon in the panoramic image and the 3-D model. Then the panoramic image is mapped by the Hammer-Aitoff equal-area projection onto the 3-D surface using texture-mapping. Finally the textured bladder model can be freely moved in a virtual environment for inspection. Using a two hemisphere bladder representation, references between panoramic image regions and their corresponding space coordinates within the bladder model are reconstructed. This additional spatial 3-D information thus assists the surgeon in navigation, documentation, as well as surgical planning.

7964-08, Session 2

Real time photoacoustic imaging of prostate brachytherapy seeds in ex vivo prostate

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The localization of brachytherapy seeds in relation to the prostate is a key step in intraoperative treatment planning (ITP) for improving outcomes in prostate cancer patients treated with low dose rate prostate brachytherapy. Transrectal ultrasound (TRUS) has traditionally been the modality of choice to guide the prostate brachytherapy procedure due to its relatively low cost and apparent ease of use. However, TRUS is unable to visualize seeds well, precluding ITP and resulting in suboptimal results. While other modalities such as X-ray and magnetic resonance imaging have been investigated to localize seeds in relation to the prostate, photoacoustic imaging has become an emerging and promising modality to solve this challenge. Moreover, photoacoustic imaging may be more practical in the clinical setting compared to other methods since it adds little additional equipment to the ultrasound system already adopted in procedure today, reducing cost and simplifying engineering steps. In this paper, we demonstrate the latest efforts of localizing prostate brachytherapy seeds using photoacoustic imaging, including real time imaging thanks to new hardware and software developments, as well as visualization of multiple seeds in actual prostate tissue. Although there are still several challenges to be met before photoacoustic imaging can be used in the operating room, we are pleased to present the current progress in this effort.

7964-09, Session 2

Optimal drug release schedule of in-situ radiosensitization of image guided permanent prostate brachytherapy

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Purpose: Planned in-situ radiosensitization may improve the therapeutic ratio of image guided 125I prostate brachytherapy. Spacers used in permanent implants may be manufactured from a radiosensitizer-releasing polymer to deliver protracted localized sensitization of the prostate. Such devices will have a limited drug-loading capacity, and the drug release schedule that optimizes outcome, under such a constraint, is not known. This work determines the optimal elution schedules for 125I prostate brachytherapy.

Methods: The interaction between brachytherapy dose distributions and chemical distribution around drug eluting spacers is modeled using a linear-quadratic (LQ) model of cell kill. Clinical brachytherapy plans were used to calculate the biologic effective dose (BED) for planned radiation dose distributions while adding the spatial distributions of radiosensitizer (determined by spacer size and diffusion-elimination coefficient:) and allowing the temporal release schedule to be optimized to minimize survival fraction subject to a constraint on the drug capacity of the eluting spacers.

Results: The greatest increase in BED is achieved by schedules with the greatest sensitization early in the implant. The relation between release schedules, and BED is presented. Moderate increases in BED can only be achieved with sensitizations lasting for at least 1 week.

Conclusion: Making brachytherapy spacers from radiosensitizer eluting polymer transforms inert parts of the implant process into a means of enhancing the effect of the brachytherapy radiation. Such an approach may increase the therapeutic ratio of prostate brachytherapy or offer a means of locally boosting the radiation effect without increasing the radiation dose to surrounding tissues.

7964-10, Session 3

Fuzzy object modeling

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To make Quantitative Radiology (QR) a reality in routine clinical practice, computerized automatic anatomy recognition (AAR) during radiological image reading becomes essential. As part of this larger goal, we present in this paper a novel fuzzy strategy for building body-wide group-wise anatomic models. While statistical approaches to modeling have been explored extensively, fuzzy approaches are rare. They have the potential to handle uncertainties and variabilities in anatomy naturally and in a manner that is computationally efficient and scalable to large problems. They can also be naturally integrated with the fuzzy connectedness framework for image segmentation. Our approach is to build a family of models, called the Virtual Quantitative Human, representing normal adult subjects at a chosen resolution of the population variables (gender, age, race,...). For demonstration, we focus on the thorax and the abdomen and male subjects 50-60 years of age. Image data are selected from our hospital patient image database after the two radiologists in the team have certified that the selected image data are normal for the body region considered. 10-15 major organs are delineated in each body region by using a combination of tools including live wire and manual tracing and painting. Models are represented and built hierarchically, the descendents representing organs contained in parent organs. The fuzzy model of each object codifies as a spatial fuzzy set the spatial variations from the ideal that may exist among a given set of shape samples of that object. Based on an index of fuzziness of the resulting models, 32 thorax data sets, and 10 organs defined in them, we found that, without changing the shape of organs in the given data sets, the hierarchical approach to modeling can effectively handle the non-linear relationships in position, scale, and orientation that seem to exist among organs in different patients.

7964-11, Session 3

The sparse data extrapolation problem: strategies for soft-tissue correction for image-guided liver surgery

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In a recent study of open abdominal image-guided liver surgery, rigid organ-based surface registration between CT-rendered liver surfaces and the corresponding laser-range scanned intraoperative partial surface resulted in an average closest-point residual of 6.1 ± 4.5 mm with maximum signed distances ranging from -13.4 to 16.2 mm. Similar to the neurosurgical environment, there appears to be a need to correct for soft tissue deformation to translate image-guided interventions to the abdomen (e.g. liver, kidney, pancreas, etc.). While intraoperative tomographic imaging equipment is available, these approaches are somewhat cumbersome and are not economically scalable to many medical centers. As a result, methods that address the sparse data extrapolation problem, i.e. the use of spatially limited intraoperative data to correct for volumetric organ-based deformations, are becoming important for improving surgical technology. In this paper, we compare and contrast three sparse data extrapolation methods to that of data-rich interpolation for the correction of deformation within a liver phantom containing 43 subsurface targets. The findings indicate that the subtleties in the initial alignment pose following rigid registration can affect the compensation for deformation in subsurface targets up to 5-10%. For the sparse extrapolative methods explored, the best deformation compensation achieved was approximately 51% (target registration error of 2.2±1.6 mm) while the data-rich interpolative method was 75% (target registration error of 0.8±0.6 mm). In addition, clinical results utilizing the methods are also presented.

7964-12, Session 3

3D density estimation in digital breast tomosynthesis: application to needle path planning for breast biopsy

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Needle insertion planning for digital breast tomosynthesis guided biopsy has the potential to improve patient comfort and intervention safety. However, a relevant planning should take into account the breast tissue deformations during the procedure. Deformable models, like finite elements, use the elastic characteristics of the breast to evaluate the deformations of tissues during needle insertion. Usually breast mechanical parameters are extracted from CT or MRI exams, but the challenging inter-modality registration motivate the search for alternative solutions. This paper presents a novel approach to locally estimate the Young modulus of the breast tissue directly from the DBT data. Our method consists in computing the glandularity index in each of the original DBT projection images, then reconstructing the tomographic sections including the local glandularity. Finally, this information is used to compute the mechanical parameters for each finite element of the deformable mesh. The first results show that using our method, a mean density value of breast zone can be obtained with an accuracy of 13%, except near the border. Moreover, the difference between the predicted

lesion displacements for a homogenous and an inhomogenous breast, tends to confirm that the accuracy of the planning will be improved by using more realistic tissue characteristics.

7964-13, Session 3

Fast interactive exploration of 4D MRI flow data

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1- or 2-directional MRI blood flow mapping sequences are an integral part of standard MR protocols for diagnosis and therapy control in heart diseases. Recent progress in rapid MRI has made it possible to acquire volumetric, 3-directional, cine images in reasonable scan time. In addition to flow and velocity measurements relative to arbitrarily oriented image planes, the analysis of 3-dimensional trajectories allows the visualization of flow patterns, local features of flow trajectories or possible paths into specific regions. This allows for advanced hemodynamic analysis in different application areas like stroke risk assessment, congenital and acquired heart disease, aneurysms or abdominal collaterals. The complexity of the 4D MRI flow datasets make the development of fast comprehensive data exploration software for advanced flow analysis a challenging task. Most existing tools address only aspects of the analysis pipeline like pre-processing, quantification or visualization, or are difficult to use for clinicians. The goal of the presented work is to provide software, which supports the whole image analysis pipeline and enables the data exploration with fast intuitive interaction and visualization methods. The implemented methods facilitate the segmentation and inspection of different vascular systems. The application of the analysis pipeline is shown for 10 cases from clinical practice, illustrating the usefulness for different clinical questions.

7964-14, Session 3

Intraoperative 3D stereo visualization for image-guided cardiac ablation

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There are commercial products which provide 3D rendered volumes, reconstructed from pre-operative CT or MRI images of a patient's heart with tools for highlighting target locations for cardiac ablation applications. However it is currently not possible to update the 3D volume intra-operatively to provide the interventional cardiologist with a more up-to-date feedback at each instant of time. It is also very useful to get a stereoscopic visual feedback to have depth perception as well. In this paper, we describe a system we have developed for real-time three-dimensional stereo visualization for cardiac ablation. A 4D ultrasound probe is used to acquire and update a 3D image volume. An electromagnetic (EM) tracking device is used to track the distal part of the ablation catheter in real-time. 3D ultrasound image volumes are processed to make the heart tissue and the catheter more visible. The rendered volume is shown in a virtual environment. The catheter can also be added as a virtual tool to this environment to achieve a higher update rate on catheter position. The ultrasound probe is also equipped with an EM tracker which is used for online registration of the ultrasound images and the catheter tracking data. The whole augmented reality scene is shown stereoscopically to enhance the depth perception for the user. We have used transthoracic echocardiography (TTE) instead of the conventional transoesophageal (TEE) or intracardiac echocardiogram (ICE). A beating heart model has been used to perform the experiments.

7964-15, Session 4

A novel class of machine-learning-driven real-time 2D/3D tracking methods: texture model registration (TMR)

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We propose a generic framework for 2D/3D image registration (texture model registration, TMR) that utilizes supervised machine learning (SML) techniques in order to overcome the limitations of traditional iterative approaches. In a first pre-computation stage, a set of digitally reconstructed radiographs (DRRs) of a randomly transformed pre-interventional three-dimensional (3D) image and an according projection geometry is computed. The generated image set is preprocessed and the characteristic image texture is extracted. The generated textures and the according training transformation parameters are the input for an arbitrary SML method (e.g. principal component regression, PCR) which derives an appropriate prediction rule. In the second online stage, the TMR algorithm receives intra-interventional two-dimensional (2D) images. By first preprocessing the images, and then applying the constructed prediction rule, the spatial transformation of the unseen 2D images is predicted.

In this work, we introduce a simple concrete TMR algorithm referred to as TMR-PCR which involves basic preprocessing and PCR for SML. Moreover, we present first evaluation results of TMR-PCR on five clinical computed tomography data sets and synthetic intra-interventional X-rays mimicking an image guided radiotherapy scenario. Based on 40000 2D/3D-registrations using TMR-PCR, and various geometric constraints, we show that this method is basically capable of predicting the spatial transformation in real-time with acceptable registration accuracy in most of the cases. Furthermore, we discuss current characteristics and limitations of the novel method, and suggest how to improve the registration accuracy for usage in image guided medical interventions.

7964-16, Session 4

Uncertainty propagation and analysis of image-guided surgery

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A successful image-guided surgical intervention requires accurate measurement of coordinate systems. Uncertainty is introduced every time a pose is measured by the optical tracking system. When we transform a measured pose into a different coordinate system, the covariance (which encodes the uncertainty of the pose) must be propagated to this new coordinate system. In this paper, we describe a method for propagating covariances estimated from registration, tracking, and instrument calibration into the tip of the surgical tool. This is clinically important, since it is at the tool tip that the clinician cares about uncertainty. We demonstrate that the propagation method, which is computed in real time as the tool moves through space, reliably computes the propagated covariance by comparing our estimate to true covariances from Monte Carlo simulations.

7964-17, Session 4

Image-based global registration system for bronchoscopy guidance

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Previous studies have shown that bronchoscopy guidance systems improve accuracy and reduce skill variation among physicians during bronchoscopy. In the past, we presented an image-based bronchoscopy guidance system that has been extensively validated in live bronchoscopic procedures. However, this system cannot actively recover from adverse events, such as patient coughing or dynamic airway collapses. After such events, the bronchoscope position is recovered only by moving back to a previously seen and easily identifiable bifurcation such as the main carina. Furthermore, the system requires an attending technician to closely follow the physician's movement of the bronchoscope to avoid misguidance. Also, when the physician is forced to make multiple bifurcation maneuvers, the system is not able to detect faulty maneuvers. We propose two system-level solutions. The first solution is a system-level guidance strategy that incorporates a global-registration algorithm to provide the physician with updated navigational and guidance information during bronchoscopy. The system can handle general navigation to a region of interest (ROI), as well as adverse events, and it requires minimal commands so that it can be directly controlled by the physician. The second solution visualizes the global picture of all the bifurcations and their relative orientations in advance and suggests the maneuvers needed by the bronchoscope to approach the ROI. Guided bronchoscopy results using human airway-tree phantoms demonstrate the potential of the two solutions.

7964-18, Session 4

High-accuracy 3D image-based registration of endoscopic video to C-arm cone-beam CT for image-guided skull-base surgery

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Registration of endoscopic video to preoperative CT facilitates high-precision surgery of the head, neck and skull-base. Conventional video-CT registration is limited by accuracy of the tracker and does not use the underlying video or CT image data. A new image-based video registration method has been developed to overcome the limitations of conventional tracker-based registration. This method adds to a navigation system based on intraoperative C-arm cone-beam CT (CBCT) providing high-accuracy registration of video to CBCT that reflects anatomical change. This registration enables visualization of the CBCT and planning data within the endoscopic video. The system incorporates a mobile C-Arm for high-performance CBCT, integrated with an optical tracking system, video endoscopy, deformable registration of preoperative CT with intraoperative CBCT, and 3D visualization. The endoscope is localized with an optical tracking system providing initialization for the image-based video-CBCT registration as in the tracker-based approach. This fast initialization is followed by a direct 3D image-based registration of the video to the CBCT. In this way, the system achieves video-CBCT registration that is both fast and accurate. Application in skull-base surgery demonstrates overlay of critical structures (e.g., carotid arteries and optic nerves) and surgical target volumes with sub-mm accuracy. Phantom and cadaver experiments show improvement in target registration error (TRE) in video overlay from 0.9 mm RMS for conventional tracker-based registration. The proposed method represents a two-fold advance - first, through registration of video to up-to-date intraoperative CBCT, and second, through direct 3D image-based video-CBCT registration, which provided sub-millimeter accuracy in TRE for all targets.

7964-19, Session 4

A novel hybrid model for deformable image registration for abdominal procedures

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In this paper, we propose a novel neuro-fuzzy hybrid transformation model for deformable image registration in intra-operative image guided procedures involving large soft tissue deformation. The hybrid model consists of two parts: a physics-based model and a mathematical function approximation model. The physics-based model is based on elastic solid mechanics to accurately model major deformation patterns of the central part of organs, and the mathematical approximation models the residual part along organ boundary. A neuro-fuzzy technique is employed to seamlessly integrate the two models into a unified hybrid model. Its unique feature is to incorporate domain knowledge of soft tissue deformation patterns and significantly reduce the number of transformation parameters, thus the dimension of search space in registration. We demonstrate the effectiveness of our hybrid model to register liver MR images in human subject study. Validation shows a mean target registration error of 1.71 mm. This technique has the potential to significantly improve intra-operative image guidance in abdominal and thoracic procedures.

7964-20, Session 4

Learning distance function for regression-based 4D pulmonary trunk model reconstruction estimated from sparse MRI data

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Congenital heart defect (CHD) is the most common birth defect and a frequent cause of death for children. Tetralogy of Fallot (ToF) is the most often occurring CHD which affects in particular the pulmonary valve and trunk. Emerging interventional methods enable percutaneous pulmonary valve implantation, which constitute an alternative to open heart surgery. While minimal invasive methods become common practice, imaging and non-invasive assessment tools become crucial components in the clinical setting. Cardiac computer tomography (CT) and cardiac magnetic resonance imaging (cMRI) are techniques with complementary properties and ability to acquire multiple non-invasive and accurate scans required for advance evaluation and therapy planning. In contrary to CT which covers the full 4D information over the cardiac cycle, cMRI usually acquires only one 3D scan of the whole heart in the end-diastolic phase and two 2D planes (long and short axes) over the whole cardiac cycle. The data acquired in this context is called sparse cMRI.

In this paper, we propose a regression-based approach for the reconstruction of the full 4D pulmonary trunk model from sparse MRI. The reconstruction approach is based on learning a distance function between the sparse MRI and the corresponding 4D CT data.

Extensive experiments performed on 80 cardiac computer tomography and magnetic resonance sequences demonstrated the average speed of 10 seconds and accuracy of 1.07mm for the proposed approach. To the best of our knowledge this is the first dynamic model of the pulmonary trunk and right ventricle outflow track estimated from sparse 4D MRI data.

7964-21, Session 5

Real-time method for bronchoscope motion measurement and tracking

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Bronchoscopy-guidance systems have been shown to improve the success rate of bronchoscopic procedures. A key technical cornerstone of bronchoscopy-guidance systems is the synchronization between the virtual world, derived from a patient's three-dimensional (3D) multidetector computed-tomography (MDCT) scan, and the real world, derived from the bronchoscope during a live procedure. Two main approaches for synchronizing these worlds exist: electromagnetic navigation bronchoscopy (ENB) and virtual bronchoscopy (VB). ENB systems require considerable extra hardware, and both approaches have drawbacks that hinder continuous robust guidance. In addition, they both require an attending technician to be present. We propose a technician-free strategy that enables real-time guidance of bronchoscopy. The approach uses measurements of the bronchoscope's movement to predict the bronchoscope's position in 3D virtual space. To achieve this, a bronchoscope model, defining the device's shape in the airway tree to a given point p, provides an insertion depth to p. In real time, our strategy compares an observed insertion depth and roll, measured by an optical sensor, to calculated insertion depths along a predefined route in the virtual airway tree. This leads to a prediction of the bronchoscope's location and orientation. To test the method, experiments involving a PVC-pipe phantom and a human airway-tree phantom verified the bronchoscope models and the entire method, respectively. The method has considerable potential for improving guidance robustness and simplicity over other bronchoscopy-guidance systems.

7964-22, Session 5

Visualization of 3D lung airway compliance and reactance using fractal 3D lung airways and impulse oscillometry measurements

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Anatomical and functional imaging systems are effective in representing a patient's pathophysiological condition. It is particularly important in the lung radiation therapy treatment planning process, where the lungs and the tumor tend to move during the imaging and treatment processes. Anatomical representations obtained from Computed Tomography (CT) depict the 3D lung anatomy. The functional representations obtained from Helium Magnetic Resonance Imaging (MRI) and Positron Emission Tomography (PET) are acquired over several breathing cycles and are thus less spatially accurate. In this paper, we present an approach that combines the CT based imaging with a pulmonary functional measurement, Impulse Oscillometry (IOS), to obtain a functional representation that is accurate both spatially and temporally. The method is described as follows: A 3D fractal cube representing the generic airway model is first developed. The 3D surface of the lungs obtained from the CT imaging is then registered with the surface of the cube using ray projection techniques. Once registered, free form deformations are then employed to warp the 3D cube to the 3D surface lung. The impulse oscillometry measurements represent the airway compliance and resistance at different airway branch points. The values of the airway compliance and reactance are then merged with the 3D warped lung airway to functionally represent the 3D lung compliance. Results show the variations in the compliance and the reactance of each patient and its variations from one treatment fraction to another.

7964-23, Session 5

Surface modeling and segmentation of the 3D airway wall in MSCT

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Airway wall remodeling in asthma and chronic obstructive pulmonary disease (COPD) is a well-known indicator of the pathology. In this context, current clinical studies aim at establishing the relationship between the airway morphological structure and its function. Multislice computed tomography data (MSCT) allows morphometric assessment of airways but requires dedicated segmentation tools for clinical exploitation. While most of the existing tools are limited to cross-section measurements, this paper develops a fully 3D approach for airway wall segmentation. Such approach relies on a deformable model which is built up as a patient-specific surface model at the level of the airway lumen and deformed to reach the outer surface of the airway wall. The deformation dynamics obey a force equilibrium in a Lagrangian framework constrained by a vector field which avoids model self-intersections. The segmentation result allows a dense quantitative investigation of the airway wall thickness with a deeper insight at bronchus subdivisions than classic cross-section methods. The developed approach has been assessed both by visual inspection of 2D cross-sections, performed by two experienced radiologists on clinical data obtained with various protocols, and by using a simulated ground truth (pulmonary CT image model). The results confirmed a robust segmentation in intra-pulmonary regions with an error in the range of the MSCT resolution, and underlined the interest of the volumetric approach versus purely 2D methods.

7964-24, Session 5

Evaluation of electromagnetically tracked transbronchial needle aspiration in a ventilated porcine lung

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Transbronchial needle aspiration (TBNA) is a common procedure to collect tissue samples from the inside of the lung for diagnostic use. However, the main drawback of the procedure is that it has to be blindly performed because the biopsy target region is not within the field of view of the bronchoscope but behind the bronchial wall. Thus, the diagnostic yield rate is low. To increase success rate of TBNA biopsy an electromagnetic trackable TBNA needle has been introduced. Nevertheless, the introduced prototype TBNA instrument was evaluated in a rigid rubber phantom without taking respiratory motion into account. The purpose of this study is to present a new TBNA needle where the electromagnetic sensor is directly integrated into a TBNA needle and to access its performance in a regularly ventilated lung. Using our previously presented navigation system, seven TBNA interventions were performed in a porcine lung during regular respiration lung movement; respectively a control computer tomography scan was acquired. We evaluated tracking accuracy of the electromagnetically tracked needle during the entire respiratory cycle for each intervention. The newly developed TBNA needle successfully operated throughout all seven interventions. According to the results, our electromagnetic TBNA tracking system is a promising approach to increase the TBNA biopsy success rate.

7964-25, Session 5

On scale invariant features and sequential Monte Carlo sampling for bronchoscope tracking

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This paper presents an improved bronchoscope tracking method for bronchoscopic navigation using scale invariant features and sequential Monte Carlo sampling. Although image-based methods are widely discussed in the community of bronchoscope tracking, they are still limited to characteristic information such as bronchial bifurcations or folds and cannot automatically resume the tracking procedure after

failures, which result usually from problematic bronchoscopic video frames or airway deformation. To address these constraints, we propose a new approach that integrates scale invariant feature-based camera motion estimation into sequential Monte Carlo sampling to achieve an accurate and robust tracking. In our approach, sequential Monte Carlo sampling is employed to recursively estimate the posterior probability densities of the bronchoscope camera motion parameters according to the observation model based on scale invariant feature-based camera motion recovery. We evaluate our proposed method on patient datasets. Experimental results illustrate that our proposed method can track a bronchoscope more accurate and robust than current state-of-the-art method, particularly increasing the tracking performance by 40.0% without using an additional position sensor.

7964-26, Session 6

Section-thickness profiling for brachytherapy ultrasound guidance

M. Peikari, T. K. Chen, Queen's Univ. (Canada); E. C. Burdette, Acoustic MedSystems, Inc. (United States); G. Fichtinger, Queen's Univ. (Canada)

Purpose: Ultrasound (US) section-thickness (the elevation beamwidth) is a significant source of localization error in tracked US navigation. It is generally assumed that the US image is of zero thickness, which contradicts the fact that the acoustic beam can only be mechanically focused at a depth corresponding to its natural frequency resulting in a finite, non-uniformed elevation beamwidth. We examine the effects of this error on transrectal ultrasound navigation used in prostate brachytherapy. Method: In this work, we have engineered a beam-profiling device (a TRUS-bridge phantom) specifically tailored for standard brachytherapy systems to generate a complete section-thickness profile of a given TRUS transducer. The device was designed in CAD software and prototyped by a 3D printer. Result: The system has been tested on an AMS Brachytherapy Stepper (Acoustic MedSystems Inc., IL, USA) but is sufficiently general to be ported to other industry-standard brachytherapy systems in the market. Possessing the knowledge of section-thickness would provide the brachytherapy applications the ability to differentiate TRUS data by their likelihood of position errors (which are otherwise treated uniformly in the current practice). Conclusion: Initial results hypothesize that beam profiling increases the accuracy of feature detections and measurements in TRUS images, thereby improving the accuracy of planning and delivery of brachytherapy.

7968-28, Session 6

Ultrasound guidance of cardiac interventions

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Surgical procedures often have the unfortunate side-effect of causing the patient significant trauma while accessing the target site. Indeed, in some cases the trauma inflicted on the patient during access to the target greatly exceeds that caused by performing the therapy. Heart disease has traditionally been treated surgically using open chest techniques with the patient being placed "on pump" - i.e. their circulation being maintained by a cardio-pulmonary bypass or "heart-lung" machine.

Recently, techniques have been developed for performing minimally-invasive interventions on the heart, obviating the formerly invasive procedures that rely on pre-operative mages, combined with real-time images acquired during the procedure. Our approach is to register intra-operative images to the patient, and use a navigation system that combines intra-operative ultrasound with virtual models of instrumentation that has been introduced into the chamber through the heart wall. This presentation will illustrate the problems associated with traditional ultrasound guidance, and review the state of the art in real-time 3D cardiac ultrasound technology. In addition, it will discuss the implementation of an image-guided intervention platform that integrates real-time ultrasound with a virtual reality environment, bringing together the pre-operative anatomy derived from MRI or CT, representations of tracked instrumentation inside the heart chamber, and the intra-operatively acquired ultrasound images.

7968-29, Session 6

Quantification of prostate deformation due to needle insertion during TRUS-guided biopsy: comparison of hand-held and mechanically stabilized systems

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Prostate biopsy is the clinical standard for the definitive diagnosis of prostate cancer. To overcome the limitations of 2D TRUS-guided biopsy systems when targeting pre-planned locations, systems have been developed with 3D guidance to improve the accuracy of cancer detection. Prostate deformation due to needle insertion and biopsy gun firing is a potential source of error that can cause target misalignments during biopsies. We use non-rigid registration of 2D TRUS images to quantify the deformation during the needle insertion and the biopsy gun firing procedure, and compare this effect in biopsies performed using a handheld TRUS probe with those performed using a mechanically assisted 3D TRUS guided biopsy system. Along the needle axis, the mean difference in deformations from the handheld and mechanically assisted biopsy systems was 0.06 mm, and the mechanical system yielded greater deformational stability of the prostate during biopsy gun firing. We also analyzed the anisotropy of the tissue motion. Our results indicated that using the mechanical biopsy system, the motion is weakly anisotropic in the direction parallel to the needle, which is preferable from a targeting standpoint given the long, narrow cylindrical shape of the biopsy core.

7968-30, Session 6

A hybrid surface/image based approach to facilitate ultrasound/CT registration

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Purpose: Registration of intra-operative ultrasound with preoperative CT is highly desirable as a navigational aid for surgeons and interventional radiologists. Image-based solutions generally achieve poor results due to substantially different image appearance of ultrasound and CT. A method is presented that uses surface information and tracked ultrasound to improve registration results.

Methods: Tracked ultrasound is combined with surface and image-based registration techniques to register ultrasound to CT. Surface data is acquired using an optically tracked range sensor, for example time-of-flight camera. Range data is registered to CT using robust point-set registration; this registration provides an approximate transformation from tracker to CT coordinates. The ultrasound probe is also optically tracked. The probe position and surface-based registration provide a first estimate for the position of the ultrasound image in CT coordinates. This estimate is subsequently refined by a final image-based registration stage.

Results: Initial tests using Coherent Point Drift algorithm for registering surface data to CT show favorable results. Tests using both simulated and real time-of-flight range data have good convergence over a wide initial translation and rotation misalignment domain.

Conclusion: Preliminary testing using time-of-flight surface data suggests that surface to CT registration may be useful as an initial guess enabling later more precise (but less robust) image based methods for registering ultrasound images to CT. We believe this method will enable image-based algorithms to robustly converge to an optimal registration solution.

A novel approach is presented addressing the problem of registering ultrasound and CT images to enable ultrasound image fusion for CT planned interventions.

Tracked ultrasound is combined with surface-based registration to provide an initial guess that enables a subsequent image-based registration step.

Initial tests using CPD algorithm with simulated and real time-of-flight range data for surface registration to CT provide favorable results.

We believe this method will enable image-based algorithms to converge to an optimal registration solution in a robust manner.

7968-31, Session 6

Calibration of a 3D ultrasound system to an electromagnetic tracking system

A. Lang, The Johns Hopkins Univ. (United States); V. Parthasarathy, A. Jain, Philips Research North America (United States)

The use of electromagnetic (EM) tracking is an important guidance tool that can be used to aid procedures requiring accurate localization such as needle injections or catheter guidance. Using EM tracking, the information from different modalities can be easily combined using pre-procedural calibration information. These calibrations are performed individually, per modality, allowing different imaging systems to be mixed and matched according to the procedure at hand. In this work, a framework for the calibration of a 3D transesophageal echocardiography probe to EM tracking is developed. The complete calibration framework includes three required steps: data acquisition, needle segmentation, and calibration. Ultrasound (US) images of an EM tracked needle must be acquired with the position of the needles in each volume subsequently extracted by segmentation. The calibration transformation is determined through a registration between the segmented points and the recorded EM needle positions. Additionally, the speed of sound is compensated for since calibration is performed in water that has a different speed then is assumed by the US machine. A statistical validation framework has also been developed to provide further information related to the accuracy and consistency of the calibration. Further validation of the calibration showed an accuracy of 1.39 mm.

7964-27, Session 7

Momentum-based morphometric analysis with application to Parkinson's disease

J. Chen, A. R. Khan, Simon Fraser Univ. (Canada); M. J. McKeown, The Univ. of British Columbia (Canada); M. F. Beg, Simon Fraser Univ. (Canada)

We propose the initial momentum of diffeomorphic metric mapping from a template region of interest (ROI) to a given ROI as a morphometic marker and demonstrate its utility in Parkinson's disease. We developed a three-step segmentation-transformation-momentum process to derive feature vectors from ROIs in a group of 42 subjects, 19 Parkinson's Disease (PD) subjects and 23 normal control (NC) subjects. Significant group differences between PD and NC subjects were detected in four basal ganglia structures including the caudate, putamen, thalamus and globus pallidus. The magnitude of regionally significant between-group differences detected ranged between 34-75%. Visualization of the different structural deformation pattern between-groups revealed that some parts of basal ganglia structure actually hypertrophy, presumably in response to more widespread atrophy. Our results of both hypertrophy and atrophy in the same structures further demonstrate the importance of morphological measures as opposed to overall volume in the assessment of neurodegenerative disease.

7964-28, Session 7

Potential predictors for the amount of intra-operative brain shift during deep brain stimulation surgery

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A number of groups have reported on the occurrence of intra-operative brain shift during deep brain stimulation (DBS) surgery. This has a number of implications for the procedure including an increased chance of intra-cranial bleeding and complications due to the need for more exploratory electrodes to account for the brain shift. It has been reported that the amount of pneumocephalus or air invasion into the cranial cavity due to the opening of the dura correlates with intra-operative brain shift. Therefore, pre-operatively predicting the amount of pneumocephalus expected during surgery is of interest toward accounting for brain shift. In this study, we used 64 DBS patients who received bilateral electrode implantations and had a post-operative CT scan acquired immediately after surgery (CT-PI). For each patient, the volumes of the pneumocephalus, left ventricle, right ventricle, third ventricle, white matter, grey matter, and cerebral spinal fluid were calculated. The pneumocephalus was calculated from the CT-PI utilizing a region growing technique that was initialized with an atlas-based image registration method. A multi-atlas-based image segmentation method was used to segment out the ventricles of each patient. The Statistical Parametric Mapping (SPM) software package was utilized to calculate the volumes of the cerebral spinal fluid (CSF), white matter and grey matter. The volume of individual structures had a moderate correlation with pneumocephalus. Utilizing a multi-linear regression between the volume of the pneumocephalus and the statistically relevant individual structures a Pearson's coefficient of $r = 0.4123$ ($p = 0.0103$) was found.

7964-29, Session 7

Simulation of brain tumor resection in image-guided neurosurgery

X. Fan, S. Ji, K. Fontaine, Dartmouth College (United States); A. Hartov, D. W. Roberts, K. D. Paulsen, Dartmouth College (United States) and Dartmouth Hitchcock Medical Ctr. (United States)

Preoperative images acquired before surgery are typically used for neuronavigation in image-guided neurosurgery. However, intraoperative brain deformation as a result of multitude of factors (e.g., gravitation, loss of cerebrospinal fluid, retraction, resection, etc.) significantly degrades the accuracy of image guidance, and must be compensated for in order to maintain sufficient accuracy in image-guidance. Biomechanical finite element models are effective techniques that assimilate intraoperative data and compute whole-brain deformation from which to generate model-updated MR images (i.e., uMR) to improve accuracy in intraoperative guidance. To date, most studies have focused on early surgical stages (i.e., after craniotomy and durotomy), whereas simulation of more complex events at later surgical stages has remained to be challenging using biomechanical models. We have developed a method to simulate partial or complete tumor resection that incorporates intraoperative volumetric ultrasound (US) and stereovision (SV), and the resulting whole-brain deformation was used to generate uMR. The 3D ultrasound and stereovision systems are complimentary to each other because they capture features deeper in the brain beneath the craniotomy and at the exposed cortical surface, respectively. In this paper, we illustrate the application of the proposed method to simulate brain tumor resection at three temporally distinct surgical stages throughout a surgery case using sparse displacement data obtained from both the US and SV systems. We demonstrate that our technique is able to maintain a model-data misfit of 1-2 mm with overall computational

efficiency of less than 30 min at later surgical stages and that it introduces minimal interruption to the surgical workflow, which suggests the potential of the method for clinical application.

7964-30, Session 7

Optimizing nonrigid registration performance between volumetric true 3D ultrasound images in image-guided neurosurgery

S. Ji, X. Fan, Dartmouth College (United States); D. W. Roberts, Dartmouth Hitchcock Medical Ctr. (United States); A. Hartov, K. D. Paulsen, Dartmouth College (United States)

Compensating for brain shift as surgery progresses is important to ensure sufficient patient-to-image registration in the operating room (OR) for reliable neuronavigation. Ultrasonography has emerged as an important and practical imaging technique for brain shift compensation either by itself or through a biomechanical model that estimates whole-brain deformation. Using volumetric true 3D ultrasound (3DUS), it is possible to nonrigidly (e.g., based on B-splines) register 3DUS images acquired at temporally different surgical stages directly to generate feature displacement maps for data assimilation in the biomechanical model. Because of the large amount of data and number of degrees-of-freedom (DOF) involved in the registration, however, a significant computational cost may be required that can adversely influence the clinical feasibility of the technique for generating model-updated MR in the OR. This paper parametrically investigates a number of registration parameters and their influence on the computational cost and registration accuracy when nonrigidly registering two 3DUS images: image volume downsampling rate, number of iterations, number of grid nodes along each direction, and maximum step length. Both digital phantom and clinical 3DUS images are employed in order to identify a set of optimized parameters that result in a computational cost of less than 5 min and a sub-millimetric displacement accuracy. The result of the study is significant because it is directly related to the clinical feasibility of the biomechanical model for generating model-updated MR for image-guidance in the OR.

7964-31, Session 7

Improved geometric factors for predicting disturbed flow at the normal carotid bifurcation

P. B. Bijari, Univ. of Toronto (Canada); L. Antiga, Orobix Srl (Italy); D. A. Steinman, Univ. of Toronto (Canada)

Recent work from our group [Lee et al., Stroke 2008;39:2341-7] has shown the primacy of bifurcation area ratio and tortuosity in determining the amount of disturbed flow at the carotid bifurcation, believed to be a local risk factor for the carotid atherosclerosis. Fast and reliable methods of extraction were previously offered based on routine 3D contrast-enhanced magnetic resonance angiography, as the necessary step along the way for large scale trials of the such local risk factors. In the present study, we refine the definitions of Lee et al's geometric factors to better reflect the underlying fluid mechanical principles. Flaring of the bifurcation, leading to flow separation, is defined by the maximum relative expansion of the common carotid artery (CCA) proximal to the bifurcation apex. The beneficial effect of curvature on flow inertia, via its suppression of flow separation, is now characterized by the tortuosity of CCA as it enters the flare region. Multiple linear regression of these new independent geometric predictors against the area exposed to low wall shear stress in 50 normal carotid bifurcations reveals adjusted R^2 of up to 0.52, superior to values achieved via multiple regression of the original two predictors, and comparable to gains made using factor analysis of a original set of 14 geometric variables. Improved prediction of disturbed flow by robust vascular geometry analysis may offer a practical pathway to large-scale studies of local risk factors in atherosclerosis.

7964-32, Session 7

Clinical study of model-based blood flow quantification on cerebrovascular data

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Diagnosis and treatment decisions of cerebrovascular diseases are currently based on structural information like the endovascular lumen. In future, clinical diagnosis will increasingly be based on functional information which gives direct information about the physiological parameters and, hence, is a direct measure for the severity of the pathology. In this context, an important functional quantity is the volumetric blood flow over time. The proposed flow quantification method uses contrasted X-ray images from cerebrovascular interventions and a model of contrast agent dispersion to estimate the flow parameters from the spatial and temporal development of the contrast agent concentration through the vascular system.

To evaluate the model-based blood flow quantification under realistic circumstances, dedicated cerebrovascular data has been acquired during clinical interventions. To this aim, a clinical protocol for this novel procedure has been defined and extensively optimized. For the verification of the measured flow results ultrasound Doppler measurements have been performed acting as ground truth.

The clinical data available so far indicates the ability of the proposed flow model to explain the in-vivo transport of contrast agent in blood. The flow map fitting results show good correspondence of flow waveform and mean volumetric flow rate with the accomplished ultrasound measurements before angiography. Hence, the method has the potential to give sufficiently accurate, quantitative flow estimates for clinical practice and to be an alternative to ultrasound Doppler.

7964-33, Session 7

Estimating blood flow velocity in angiographic image data

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We propose a system to estimate blood flow velocity in angiographic image data for patient-specific blood flow simulations. Angiographies are acquired routinely for diagnosis and before treatment of vascular diseases. Projective blood flow is measured in digital subtraction X-ray angiography (2D-DSA) images by tracking contrast agent propagation, spatial information is added by re-projecting 2D centerline pixels to the reconstructed 3D X-ray rotation angiography (3D-RA) data of the same subject. Ambiguities caused by occluding vessels from the virtual viewpoint of the acquired 2D-DSA image are resolved by a graph-based approach. The blood flow velocity can be used as boundary condition for exact blood flow simulations that can help physicians to understand hemodynamics of the vasculature. Our focus is to analyze cerebral angiographic data. We performed several experiments with phantom and patient data that proved the accuracy and the functionality of our method. We evaluated experimentally the projective flow estimation method and the re-projection method. We measured mean deviations to the ground truth between 11 % and 15.7 % for the phantom data. We also showed the ability of our method to produce plausible results with patient-data.

7964-56, Poster Session

System for robust bronchoscopic video distortion correction

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Bronchoscopes contain wide-angle lenses that produce a large field of view but suffer from radial distortion. For image-guided bronchoscopy, geometric calibration including distortion correction is essential for comparing video images to renderings developed from 3D computed-tomography (CT) images. This paper describes an easy-to-use system for bronchoscopic video-distortion correction and studies the robustness of the resulting calibration over a wide range of conditions. The internal calibration method integrated into the system incorporates a well-known camera calibration framework devised for general camera-distortion correction. The robustness study considers the calibration results as follows: (1) varying lighting during video capture, (2) using different number of captured images for parameter estimation, (3) changing camera pose with respect to the calibration pattern, (4) recording temporal changes in estimated parameters, and (5) comparing parameters between different bronchoscopes of a same model. Multiple bronchoscopes were successfully calibrated under a variety of conditions.

7964-57, Poster Session

Online temporal synchronization of pose and endoscopic video streams

O. Gueler, Innsbruck Medical Univ. (Austria); Z. R. Yaniv, Georgetown Univ. (United States); W. Freysinger, Innsbruck Medical Univ. (Austria)

Computer assisted navigation systems that combine real-time endoscopy images with pre-operative volumetric data sets aim at improving the physician's understanding of the underlying anatomical structures. To achieve accurate and safe guidance these systems are required to provide a consistent representation of the physical world. This implies that all data streams are synchronized. In our case, we are dealing with synchronization of tracking data and a video stream obtained by a tracked endoscope. Previously, such synchronization was obtained pre-operatively using phantoms. This type of approach assumes a constant latency between the data streams and is less desirable for clinical use due to the required additional hardware. In this work we describe an online temporal synchronization method. The method is based on the observation that in clinical practice the endoscope is not in constant motion. By identifying corresponding stationary points in the video and tracking streams temporal synchronization can be performed online in a manner that is transparent to the user. Initial evaluation of our approach in a laboratory study has shown that it provides comparable estimates to a phantom based approach we had previously proposed.

7964-58, Poster Session

Ultrasound calibration framework for the image-guided surgery toolkit

P. J. Stolka, The Johns Hopkins Outpatient Ctr. (United States); H. Kang, The Johns Hopkins Univ. (United States); E. Boctor, The Johns Hopkins Outpatient Ctr. (United States); Z. R. Yaniv, Georgetown Univ. (United States)

Registration is a key technology in image-guided navigation systems. By aligning pre-operative images with the intra-operative setting these systems provide visual feedback that improves the physician's understanding of the spatial relationships between anatomical structures and surgical tools. Most often the alignment is obtained using fiducials. Another option is to replace the use of fiducials with intra-operative imaging. Two dimensional ultrasound (US) is a widely available intra-operative non-ionizing imaging modality. To utilize this modality for registration one must first perform spatial calibration of the US. In this work we describe the implementation of three spatial calibration methods as part of the image-guided surgery toolkit (IGSTK). The toolkit currently supports most commercially available tracking devices in addition to image-acquisition using a frame-grabber. These two components are required for US calibration. The implementation follows the IGSTK calibration framework, separating algorithmic aspects from user interaction aspects of the calibration. Our calibration framework includes three methods. The first is a phantom-less method using a tracked pointer tool in addition to the tracked US, the second method is based on a simple plane phantom and the third method is based on a phantom designed to enable fully automated calibration.

7964-59, Poster Session

Motion compensation by registration-based catheter tracking

A. B. Brost, A. Wimmer, Friedrich-Alexander-Univ. Erlangen-Nürnberg (Germany); R. Liao, Siemens Corporate Research (United States); J. Hornegger, Friedrich-Alexander-Univ. Erlangen-Nürnberg (Germany); N. Strobel, Siemens AG (Germany)

The treatment of atrial fibrillation has gained increasing importance in the field of computer-aided interventions. State-of-the-art treatment involves the electrical isolation of the pulmonary veins attached to the left atrium under fluoroscopic X-ray image guidance. Due to the rather low soft-tissue contrast of X-ray fluoroscopy, the heart is difficult to see. To overcome this problem, overlay images from pre-operative 3-D volumetric data can be used to add anatomical detail. Unfortunately, these overlay images are static at the moment, i.e., they do not move with respiratory and cardiac motion. The lack of motion compensation may impair X-ray based catheter navigation, because the physician could potentially position catheters incorrectly. To improve overlay-based catheter navigation, we present a novel two stage approach for respiratory and cardiac motion compensation. First, a cascade of boosted classifiers is employed to segment a commonly used circumferential mapping catheter which is firmly fixed at the ostium of the pulmonary vein during ablation. Then, a 2-D/2-D model-based registration is applied to track the segmented mapping catheter. Our novel hybrid approach was evaluated on 10 clinical data sets consisting of 498 fluoroscopic monoplane frames. We obtained an average 2-D tracking error of 0.61 mm, with a minimum error of 0.26 mm and a maximum error of 1.62 mm. These results demonstrate that motion compensation using registration-based catheter tracking is both feasible and accurate. Using this approach, we can only estimate in-plane motion. Fortunately, compensating for this is often sufficient for EP procedures where the motion is governed by breathing.

7964-60, Poster Session

First steps towards initial registration for electrophysiology procedures

A. B. Brost, Friedrich-Alexander-Univ. Erlangen-Nürnberg (Germany); F. Bourier, Univ. Regensburg (Germany); L. Yatziv, Siemens Corporate Research (United States); M. Koch, J. Hornegger, Friedrich-Alexander-Univ. Erlangen-Nürnberg (Germany); N. Strobel, Siemens AG (Germany); K. Kurzidim, Univ. Regensburg (Germany)

Atrial fibrillation is the most common heart arrhythmia and a leading cause of stroke. The treatment option of choice is radio-frequency catheter ablation, which is performed in electrophysiology labs using C-Arm X-ray systems for navigation and guidance. The goal is to electrically isolate the pulmonary vein-left atrial junction thereby rendering

myocardial fibers responsible for induction and maintenance of AF inactive. The use of overlay images for fluoroscopic guidance may improve the quality of the ablation procedure, and can reduce procedure time. Overlay images, acquired using CT, MRI, or C-arm CT, can add soft-tissue information, otherwise not visible under X-ray. MRI can be used to image a wide variety of anatomical details without ionizing radiation. In this paper, we present a method to register a 3-D MRI volume to 2-D biplane X-ray images using the coronary sinus. Current approaches require registration of the overlay images to the fluoroscopic images to be performed after the trans-septal puncture, when contast agent can be administered. We present a new approach for registration to align overlay images before the trans-septal puncture. To this end, we manually extract the coronary sinus from pre-operative MRI and register it to a multi-electorde catheter placed in the coronary sinus.

7964-61, Poster Session

3D imaging of myocardial perfusion and coronary tree morphology from a single rotational angiogram

G. Lauritsch, Siemens Medical AG (Germany); C. Rohkohl, Friedrich-Alexander-Univ. Erlangen-Nürnberg (Germany) and Siemens AG, Healthcare Sector (Germany); J. Hornegger, Friedrich-Alexander-Univ. Erlangen-Nürnberg (Germany) and Erlangen Graduate School in Advanced Optical Technologies (SAOT) (Germany); A. Sinha, J. Brachmann, Klinikum Coburg (Germany); J. Rieber, Ludwig-Maximilians-Univ. München (Germany); H. Rittger, Klinikum Coburg (Germany)

Diagnosis and treatment of coronary heart disease are performed in the catheter laboratory using an angiographic X-ray C-arm system. The morphology of the coronary tree and potentially ischemic lesions are determined in 2D projection views. The hemodynamic impact of the potentially ischemic lesion would be a valuable impact for treatment decision. Using other modalities for functional imaging is disrupting the clinical workflow since the patient has to be transferred from the catheter laboratory to another scanner, and back to the catheter laboratory for performing the treatment. In this work a novel technology is used for simultaneous 3D imaging of first pass perfusion and the morphology of the coronary tree from a single rotational angiogram. A selective, single shot of contrast agent of less than 20ml directly into the coronaries is sufficient for a proper contrast resolution. Due to the long acquisition time cardiac motion has to be considered. A novel reconstruction technique for estimation and compensation of cardiac motion from the acquired projection data is used. The overlay of the 3D structure of the coronary tree and the perfusion image shows the correlation of myocardial areas and the associated coronary sections supporting that region. In a case example scar lesions caused by a former myocardial infarct are investigated. A first pass perfusion defect is found which is validated by a late enhancement magnetic resonance image. No ischemic defects are found. The non vital regions are still supported by the coronary vasculature.

7964-62, Poster Session

Intensity-based hierarchical clustering in CT-scans: application to interactive segmentation in cardiology

J. Hadida, C. Desrosiers, L. Duong, Ecole de Technologie Supérieure (Canada)

The segmentation of anatomical structures in Computed Tomography Angiography (CTA) is a pre-operative task useful in image guided surgery. Even though very robust and precise methods have been developed to help achieving a reliable segmentation (level sets, active contours, etc), it remains very time consuming both in terms of manual interactions and in terms of computation time. The goal of this study is to present a fast and interactive method to find coarse anatomical structures in CTA, based on hierarchical clustering. The algorithm is organized as follows: first, a fast histogram interpolation method is proposed to compute a piecewise constant mask. A second step then indexes all the space-connected regions in the piecewise constant mask. Finally, a hierarchical clustering is achieved to build a graph representing the connections between the various regions in the piecewise constant mask. This step builds up a structural knowledge about the image. Several interactive features for segmentation are presented, for instance association or disassociation of anatomical structures. A comparison with the Mean-Shift algorithm is presented.

7964-63, Poster Session

4D motion animation of coronary arteries from rotational angiography

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For diagnosis and therapy of heart diseases in the catheter laboratory, the common approach in clinical routine is to apply 2-D coronary angiography using C-arm systems. Reconstruction of 3-D images is an active and challenging research field. Spatial 3-D imagination of the vessel tree may be essential to the clinician for precise roadmapping of the intervention. Additionally, an animated visualization of the coronary arteries may provide new possibilities for various applications like dynamic roadmapping or determining vital properties. Rohkohl et al. proposed a method for tomographic cone-beam 3-D reconstruction of the coronary arteries from one single rotational angiography C-arm acquisition. The algorithm achieves a static 3-D image and an estimate of the non-periodic motion of that image. The optimization for this non-periodic 4-D deformation model is done in the domain of acquired projections and thus underdetermined because of missing information. As result, while this deformation model was shown to significantly improve reconstruction quality, it does not allow proper animation. It lacks the motion information in-depth along viewing direction since this cannot be measured in the projections. However, this missing in-depth direction can be seen within other projections. We propose an algorithm that solves this problem of missing information by incorporating the assumed periodicity of the heart beat. Given the deformation model resulting from the reconstruction step, our algorithm robustly computes a periodic motion model within short clinical feasible time of less than one minute.

7964-64, Poster Session

A novel bronchoscope tracking method for bronchoscopic navigation using a low cost optical mouse sensor

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Image-guided bronchoscopy usually requires to track the bronchoscope camera position and orientation to align the preinterventional 3-D computed tomography (CT) images to the intrainterventional 2-D bronchoscopic video frames. Current state-of-the-art image-based algorithms often fail in bronchoscope tracking due to shortages of information on depth and rotation around the viewing (running) direction of the bronchoscope camera. To address these problems, this paper presents a novel bronchoscope tracking method for bronchoscopic

navigation based on a low-cost optical mouse sensor, bronchial structure information, and image registration. We first utilize an optical mouse senor to automatically measure the insertion depth and the rotation of the viewing direction of the bronchoscope. We integrate the outputs of such a 2-D sensor by performing a centerline matching on the basis of bronchial structure information before optimizing the bronchoscope camera motion parameters during image registration. An assessment of our new method is implemented on phantom data. Experimental results

illustrate that our proposed method is a promising means for bronchoscope tracking, compared to our previous image-based method, signicantly improving the tracking performance.

7964-65, Poster Session

Image-based endoscope motion estimation using prior probabilities

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Image-based camera motion estimation from video or still images is a difficult problem in the field of computer vision. Many algorithms have been proposed for feature detection and matching, linear camera motion estimation, and nonlinear bundle adjustment. These steps all face challenges in practical applications: locating features can be difficult given the limited capabilities of current feature detectors, camera motion inference can fail in the presence of noise and outliers, and bundle adjustment often finds suboptimal local minima. Endoscopic video also features nonrigid scenery and large barrel distortion. In this paper, we study these problems and propose the use of prior probabilities to stabilize camera motion estimation for the application of computing endoscope motion sequences in colonoscopy.

It is possible to characterize typical endoscope motion sequences in colonoscopy. As the endoscope is restricted to move within a roughly tube-shaped structure, forward/backward motion is expected, with only small amounts of rotation and horizontal movement. We formulate a probabilistic model of endoscope motion by maneuvering an endoscope and attached magnetic tracker through a synthetic colon model and fitting a distribution to the observed tracker motion. This allows us to estimate the probability of the current endoscope motion given previously observed motion in the sequence. We add these prior probabilities as additional penalty terms in RANSAC to help reject improbable motion parameters caused by outliers and other problems with medical data. This paper presents the theoretical basis of our method along with preliminary results on indoor scenes and synthetic colon images.

7964-66, Poster Session

Detection of inflating balloon in optical coherence tomography images of a porcine artery in a beating heart experiment

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The beating heart setup has been very beneficial in developing our intravascular optical coherence tomography (IVOCT) system. Extracting quantitative information from IVOCT images in a beating heart experiment can be of high utility, not only from the system development perspective, but also from the cardiovascular research point of view. In this paper, an automatic edge detection algorithm is applied for detection of an inflating balloon in a porcine artery in a beating heart experiment. A compliant balloon is used to displace the optically scattering blood. Swept-source optical coherence tomography (SS-OCT) is used for imaging. SS-OCT imaging is performed at 30 frames per second. The balloon, when not inflated, is surrounded by blood. It can be inflated to pressures of up to 1 atm. Once inflated, the balloon displaces the blood and engages the arterial wall. Therefore, at higher inflation pressures, characterization of the diameter of the inflated balloon leads to a characterization of the luminal diameter of the vessel. This provides a less complicated tool for diameter characterization in comparison with techniques such as fluoroscopy. Characterization of balloon diameter is presented, based on 356 IVOCT frames that were acquired during inflation. The estimated balloon diameter increases from 1.8 mm to 2.8 mm. Contractions of the artery during the heart beat can be traced on the curve characterizing the balloon diameter.

7964-68, Poster Session

Automatic measurement of contrast bolus distribution in carotid arteries using a C-arm angiography system to support interventional perfusion imaging

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Perfusion CT and MRI are the common methods for stroke diagnosis but they are not available in an interventional environment to support stroke therapy. We are currently investigating to use an interventional C-arm angiography system capable of CT-like imaging (C-arm CT) to measure tissue perfusion. Our protocol uses intra-arterial contrast bolus injections at the aortic arch to increase the signal-to-noise ratio of the measured contrast curves.

Careful selection of the injection catheter location at the aortic arch is necessary to ensure uniform contrast distribution in the common carotid arteries (CCA) which is necessary to compare perfusion in the left and right hemispheres.

In this work we present a method to support optimal injection catheter placement by providing additional quantitative information about the distribution of the contrast bolus in the CCAs. This fully automatic method uses digital subtraction angiography (DSA) images following a test bolus injection by segmenting both CCAs and computing parameters to compare the contrast distribution. We have tested the method in DSA data sets from 8 healthy pigs. Our method achieved successful segmentation of both CCAs in all data sets. Quantitative contrast flow information could be computed in all data sets and they were in good agreement with the visual evaluation of the contrast flow.

This new method may help to optimize injection catheter placement for interventional perfusion C-arm CT imaging with intra-arterial contrast bolus injections.

7964-69, Poster Session

The feasibility of real-time bladder mapping using a stereotactic navigational system

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Stereotactic navigational devices have been implemented in neurosurgery, orthopedics and ear-nose-throat to improve surgical accuracy. However, the feasibility of navigating inside the bladder has not yet been investigated. Occasionally, transurethral resections of bladder tumors (TURBTs) are impeded by bleeding and cloudiness inside the bladder and, consequently, the bladder lesions are not found back easily. In addition, bladder lesions are often concealed when viewed with the camera some distance away from the bladder wall.

The aim of the study is to investigate the feasibility of real-time bladder mapping using the Medtronic Stealthstation system, without the use of pre-operative images. Ten patients were scheduled for a TURBT and were included in the study. During the TURBT procedure, the spatial coordinates of the bladder lesions were recorded two times independently, after filling the bladder with a fixed volume of 390 ml. The distance between the spatial coordinates of two consecutive measurements, in millimeters, was calculated. We found that bladder lesions can be found back using the navigational system with an accuracy of less than 12 mm. Real-time bladder navigation is feasible without the necessity of pre-operative images or calibration. If the coordinates are directly superimposed on the video image this could facilitate the retrieval of bladder lesions during TURBT. This system could reduce the stress for the surgeon and decrease the operating time. Furthermore, it could improve the success rate of the operation, reduce the recurrence rates, improve the patient's outcome and save overall treatment costs.

7964-70, Poster Session

Accuracy assessment of fluoroscopy-transesophageal echocardiography registration

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This study assessed the accuracy of a new transesophageal (TEE) ultrasound (US) - fluoroscopy registration technique designed to guide percutaneous aortic valve replacement. In this minimally invasive procedure, a valve is inserted into the aortic annulus via a catheter. Navigation and positioning of the valve is guided primarily by intra-operative fluoroscopy. Poor anatomical visualization of the aortic root region can result in incorrect positioning, leading to heart valve embolization, obstruction of the coronary ostia and acute kidney injury. The use of TEE US images to augment intra-operative fluoroscopy provides significant improvements to image-guidance.

Registration was achieved using an image-based TEE probe tracking technique and US calibration. TEE probe tracking was accomplished using a single-perspective pose estimation algorithm. Pose estimation from a single image allowed registration to be achieved using only images collected in standard OR workflow. Accuracy of this registration technique was assessed using three models: a point target phantom, a cadaveric porcine heart with implanted fiducials, and live porcine images. Results demonstrated that registration could be achieved with an RMS error of less than 1.5mm, which is within the clinical accuracy requirements of 5mm. US-fluoroscopy registration based on single-perspective pose estimation demonstrates promise as a method for providing guidance to percutaneous aortic valve replacement procedures. Future work will focus on real-time implementation and a visualization system that can be used in the operating room.

7964-71, Poster Session

A single-imager miniature stereoscopic endoscope

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We have built a prototype, small 5-mm-diameter stereoscopic endoscopy system that combines spatial perception comparable to much bulkier 12-mm-diameter stereo endoscopes with the flexibility of standard, unmodified high-definition (HD) endoscopic cameras for stereo capture.

The system focuses around our custom-designed 5-mm-diameter, dual-tube, wide-IPD entrance stereo endoscope. This scope has a unique, combined exit optical path which allows both left and right channels to be simultaneously projected onto a standard HD endoscopic camera. The camera's HD images are streamed into a computer which separates, distortion-corrects and aligns the two images, then displays them on a stereoscopic monitor for surgeons and assistants. Optically, our near-diffraction-limited design provides to each eye a resolution comparable or better than that of standard 5-mm mono-scopes.

The 5-mm stereo system's benefits go beyond mere miniaturization: for cost savings, the capture camera uses unmodified off-the-shelf HD cameras already widely available in hospitals. Our stereo scope just snaps on like any other traditional mono scope; no adapter is needed.

Our goal was not only to create a much smaller stereo scope, but also to allow the huge existing inventory of standard scopes and camera systems already purchased by hospitals to be utilized efficiently. Initial animal studies with this new device will be conducted in July 2010, with results to be included in the full paper.

7964-72, Poster Session

Mixed variable optimization for radio frequency ablation planning

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Purpose: A method is presented for optimization of multiple ablation needle placements to provide sufficient and efficient coverage of a tumor for thermal therapy, while respecting clinical needs such as limiting the sites of needle insertions at the pleura/liver surface, choosing valid probe trajectories and locations, avoiding ablation of critical structures, reducing ablation of healthy tissue and minimizing overlap of ablation zones.

Methods: The ablation optimizer treats each ablation location independently, and the number of ablation needle placements itself is treated as a variable to be optimized. This allows the process to be iterative, with sequential feedback during the ablation. This allows for sequential re-optimization after each placement, helping to define the next steps of plan implementation. The optimization method uses a new class of derivate-free algorithms for solving a non-linear mixed variable problem with hard and soft constraints derived from clinical images. The new method uses discretization of the ablation volume, which can accommodate irregular shapes of the ablation zone.

Results: The non-gradient based strategy produces new candidates to yield a feasible solution within a few iterations. In simulation experiments, this strategy typically reduced the ablation zone overlap (by 46%) and reduced ablated healthy tissue (by 29%), in a single iteration, resulting in a feasible solution to be found within 35 iterations.

Conclusion: Our method for optimization provides efficient implementation for planning the coverage of a tumor, while respecting clinical constraints. The ablation planning can be combined with navigation assistance to enable accurate translation and feedback of the plan.

7964-73, Poster Session

Automatic fiducial localization in ultrasound images for a thermal ablation validation platform

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PURPOSE: Development of ultrasound-based tumor ablation monitoring systems requires extensive validation. Validation is based on the comparison of ablated regions, computed from ultrasound images, to the

ground truth region observed on histopathology images. Registration of ultrasound and histopathology images can be efficiently implemented by localizing fiducial lines embedded in the test phantom. Manual fiducial localization is time consuming and may be inaccurate. Current automatic localization algorithms were designed for use on images containing easily detectable fiducials in clear water, while the images produced by the ablation monitoring platform contain fiducials and ablated tissue embedded in tissue-mimicking gel. Our goal was to develop an automatic fiducial localization algorithm for the ablation monitoring platform. METHOD: A previously existing algorithm for detecting fishing line in water for ultrasound probe calibration, created by Chen et al., was tested on ultrasound images of an ablation phantom. Fiducial and line point detection parameters were determined by running the algorithm multiple times with different parameter sets and searching for the set that results in the best detection success rate. The fiducial intensity scoring method was modified to use intensities from an unaltered image; this greatly reduced the number of incorrectly identified fiducials. Line finding was modified to suit the ablation phantom geometry. RESULTS: The new algorithm was tested by comparing the automatic localization results to manually identified fiducial positions. Using the optimized parameters, it was found to have a 94.1 % success rate on the tested images. Fiducial localization error was defined as the difference between the manually segmented positions and the positions found by the algorithm. Fiducial localization error was -0.04±0.18mm along the x-axis, and -0.09±0.14mm along the y-axis. CONCLUSION: We have developed an automatic algorithm that detects line fiducials at a high success rate in complex phantoms containing a tissue sample embedded in tissue-mimicking gel.

7964-74, Poster Session

Architecture of a high-performance surgical guidance system based on C-arm cone-beam CT: software platform for technical integration and clinical translation

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The development of a software architecture for cone-beam CT (CBCT) guided surgery is detailed that binds open-source surgical navigation libraries and integrates intraoperative CBCT with novel, application-specific registration and guidance technologies. The architecture is shown to accelerate translation of task-specific technical development in applications ranging from orthopaedic to head-and-neck and thoracic surgery. This work describes a system based upon a prototype mobile C-arm for high-quality CBCT and achieves a modular architecture that enables integration of different tools and devices consistent with surgical workflow in each of these applications. Specific modules are developed according to the surgical task, including: 3D-3D deformable registration, bringing preoperative image and planning data to the most up-to-date CBCT; 3D-2D registration of planning and image data to real-time fluoroscopy; infrared, electromagnetic, and video-based trackers used individually or in hybrid arrangements; augmented overlay of image and planning data in endoscopic or in-room video; real-time “virtual fluoroscopy” computed from GPU-accelerated digitally reconstructed radiographs (DRRs); and multi-modality image display. The platform aims to minimize offline data processing by exposing quantitative tools that analyze and communicate factors of geometric precision online. The system was translated to preclinical phantom and cadaver studies for assessment of fiducial (FRE) and target registration error (TRE), yielding sub-mm accuracy in targeting and video overlay within periodically updated CBCT scans. The work culminates in the development of a CBCT guidance system (reported here for the first time) on a new clinical prototype C-arm that leverages the technical developments in a high-performance system for translation to clinical studies.

7964-75, Poster Session

Adaptive bilateral filter for image denoising and its application to in-vitro time-of-flight data

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Image-guided therapy systems generally require registration of pre-operative planning data with the patient’s anatomy. One common approach to achieve this is to acquire intra-operative surface data and match it to surfaces extracted from the planning image. Although increasingly popular for surface generation in general, the novel Time-of-Flight (ToF) technology has not yet been applied in this context. This may be attributed to the fact that the ToF range images are subject to considerable noise. The contribution of this study is two-fold. Firstly, we present an adaption of the well-known bilateral filter for denoising ToF range images based on the noise characteristics of the camera. Secondly, we assess the quality of organ surfaces generated from ToF range data with and without bilateral smoothing using corresponding high resolution CT data as ground truth. According to an evaluation on five porcine organs, the root mean squared (RMS) distance between the denoised ToF data points and the reference CT surfaces ranged from 3.0 mm (lung) to 9.0 mm (kidney). This corresponds to an error-reduction of up to 36% compared to the error of the original ToF surfaces.

7964-76, Poster Session

Development of a novel laser range scanner

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Image-guided surgery in the brain and other organs may be augmented by mathematically modeling the deformation of soft tissue. Biomechanical models require the challenging task of designating accurate boundary conditions to the tissue of interest. Laser range scanning the organ surface intraoperatively provides a cost effective and accurate means of supplying boundary conditions. A novel laser range scanner (LRS) was designed, developed, and analyzed with the goal of providing intraoperative surface data during neurosurgery. The scanner is fitted with infrared emitting diodes to be optically tracked in the operating room. The design notably includes a single-lens system capable of acquiring the geometric information (as a Cartesian point cloud) via laser illumination and CCD collection, as well as the color information via visible light collection on the same CCD. The geometric accuracy was assessed by scanning a machined phantom of known dimensions and comparing relative distances of landmarks from the point cloud to the known distances. The ability of the LRS to be tracked was evaluated by perturbing its orientation in front of the optical tracking camera and recording the number of diodes visible to the camera at each orientation. The scanning accuracy test resulted in an RMS error of 1.25 mm with standard deviation of 0.59 mm. The diode visibility test showed that four diodes were visible in most of the probable operating orientations. Intraoperative collection of cortical surface scans using the new LRS is currently underway.

7964-77, Poster Session

Hardware and systems for interactive real-time cardiac magnetic resonance imaging

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Real-time magnetic resonance imaging (MRI) has many advantages compared to traditional MRI and can expand its application for the visualization of dynamic changes in cardiac structure and functions without cardiac gating, as the fast data acquisition beats the motion resulting from heart beating and lung breathing and apparently "freeze" them during the short image acquisition window. To do real-time imaging with a standard MRI scanner, special pulse sequences and image reconstruction algorithms must be developed to improve the temporal resolution with acceptable spatial resolution and to accept on-fly the interactively prescribed imaging planes and apply them. Further real-time MRI needs the development of software and hardware infrastructure that facilitates rapid interactive examination.

In this paper we report the system integration of hardware, pulse sequences, and image reconstruction algorithms that enabled magnetic resonance imaging (MRI) to visualize dynamic processes in real time with high spatial resolution, high temporal resolution, and various types of image contrast without requiring cardiac gating or breath-holding. Preliminary results of usability test indicate that on average a cardiac practitioner is able to prescribe four standard cardiac views within about two and a half minutes with about 5mm displacement errors for the two chamber and the LVOT views and less than 20 degree orientation error for the SAO view.

7964-79, Poster Session

Clinical implementation of intraoperative cone-beam CT in head and neck surgery

M. J. Daly, Ontario Cancer Institute (Canada) and Univ. of Toronto (Canada); H. Chan, J. Qiu, J. Irish, Ontario Cancer Institute (Canada); J. Siewerdsen, The Johns Hopkins Univ. (Canada)

A prototype mobile C-arm for cone-beam CT (CBCT) has been translated to a prospective clinical trial in head and neck surgery. The flat-panel CBCT C-arm was developed in collaboration with Siemens Healthcare, and demonstrates both sub-mm spatial resolution and soft-tissue visibility at low radiation dose (e.g., <1/5th of a typical diagnostic head CT). CBCT images are available ~15 seconds after scan completion (~1 min acquisition) and reviewed at bedside using custom 3D visualization software based on the open-source Image-Guided Surgery Toolkit (IGSTK). The CBCT C-arm has been successfully deployed in 15 head and neck cases and streamlined into the surgical environment using human factors engineering methods and expert feedback from surgeons, nurses, and anesthetists. Intraoperative imaging is implemented in a manner that maintains operating field sterility, reduces image artifacts (e.g., carbon fiber OR table) and minimizes radiation exposure. CBCT images reviewed by 4 surgeons and 1 radiologist indicate bony detail and soft-tissue visualization sufficient for intraoperative guidance, with additional artifact management (e.g., metal, truncation, and scatter) promising further improvements. Expert feedback from surgical staff suggests a role for intraoperative CBCT in guiding complex head and neck surgical tasks, including planning mandible and maxilla resection margins, guiding subcranial and endonasal approaches to skull base tumours, and verifying maxillofacial reconstruction alignment. Ongoing translational research into complimentary subsystems include novel methods for real-time tool tracking, fusion of endoscopic video and CBCT, deformable registration of preoperative volumes and planning contours with intraoperative CBCT, and kinematic surgical tool motion models.

7964-80, Poster Session

Validation of visual surface measurement using computed tomography

R. E. Ellis, A. M. VanBerlo, A. R. Campbell, Queen's Univ. (Canada)

Although dysesthesia is a common and persistent surgical complication, there is no accepted method for quantitatively tracking affected skin. To address this, two types of computer vision technologies were tested in a total of four configurations. Surface regions on plastic models of limbs were delineated with colored tape, imaged, and compared with computed tomography scans. The most accurate system used visually projected texture captured by a binocular stereo camera, capable of measuring areas to within 0.05% of the ground-truth areas with 1.4% variance. This simple, inexpensive technology shows promise for postoperative monitoring of dysesthesia surrounding surgical scars.

7964-81, Poster Session

Alignment and calibration of high frequency ultrasound and optical coherence tomography transducers using a dual-wedge tri-step phantom

N. Afsham, K. Chan, S. Tang, R. N. Rohling, L. Pan, The Univ. of British Columbia (Canada)

This paper introduces a novel alignment and calibration method for high frequency ultrasound (HFUS) and optical coherence tomography (OCT) 1D transducers. 2D images are constructed by means of translation of the transducers using a linear motor stage. Physical alignment of the transducers is needed in order to capture images of the same cross-sectional plane, and calibration is needed to determine the relative coordinates of the images, including the image skew. A dual-wedge tri-step phantom is created for both alignment and calibration. This phantom includes two symmetrical wedges and three steps that provide the user with visual feedback on how well the scan plane is aligned with the midplane of the phantom. The phantom image consists of five line segments, each of which corresponds to one of the wedges or steps. The slopes and positions of the lines are extracted from the image and compared with the phantom model. The scan plane parameters are found so that the difference between the model and extracted features is minimized. The main advantage of this phantom is that only one frame is required to determine translations, orientations, and skew parameters of the scan plane with respect to the phantom. Experimental results with ocular imaging show the ability to achieve alignment based on this method and its potential for medical applications.

7964-82, Poster Session

3D-guided CT reconstruction using time-of-flight camera

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We propose the use of a time-of-flight (TOF) camera to obtain the patient's body contour in 3D guided imaging reconstruction scheme in CT and C-arm imaging with truncated projection. In addition to intensity, TOF camera provides the 3D coordinates of each point in the captured scene with respect to the camera coordinates. Information from the TOF camera was used to obtain a digitized surface of the patient's body. The digitization points are transformed to X-Ray detector coordinates by registering the two coordinate systems. For the slice-of-interest, a 2D contour of the body surface represented by a white mask on a black background is formed. Radon transform is applied to the masked region to generate the 'trust region' of the entire body for the projection data. The generated 'trust region' is integrated as an input to augment the projection data. It is used to estimate the truncated, unmeasured projections using consistency conditions [1]. Finally the image is reconstructed using the source and estimated projection data. The proposed method is evaluated using a physical phantom. Projection data for the phantom was obtained using a C-arm system. Significant improvement in the reconstructed image quality near the boundaries was observed using the proposed method as compared to that without truncation correction. This work shows that the proposed 3D guided CT imaging reconstruction using TOF camera represents a feasible solution to the truncated projection data problem.

7964-83, Poster Session

Transorbital therapy delivery: phantom testing

R. L. Galloway, Jr., L. A. Mawn, Vanderbilt Univ. (United States)

We have developed a combined image-guided and minimally invasive system for the delivery of therapy to the back of the eye. It is composed of a short 4.5 mm diameter laparoscope with a magnetic tracker embedded in the tip. In previous work we have defined an optimized fiducial placement for accurate guidance to the back of the eye and are now moving to system testing.

The fundamental difficulty in testing performance is establishing a target in a manner which closely mimics the physiological task. We have to have a penetrable material which obscures line of sight, similar to the orbital fat. In addition we need to have some independent measure of knowing when a target has been reached to compare to the ideal performance. Lastly, the target cannot be rigidly attached to the skull phantom since the optic nerve lies buried in the orbital fat.

We have developed a skull phantom with white cloth stellate beads supporting a correctly sized globe. Placed in the white beads are a red, blue, orange and yellow beads. One of the colored beads has been soaked in barium to make it bright on CT. The user guides the tracked laparoscope to the target as defined by the images and tells us its color. We record task accuracy and time to target. We have tested this with 28 residents, fellows and attending physicians. Each physician performs the task twice guided and twice unguided. Results will be presented.

7964-84, Poster Session

Expansion and dissemination of ‘a standardized accuracy and precision assessment technique’

D. M. Kwartowitz, Clemson Univ. (United States) and Mayo Clinic (United States); R. E. Riti, Clemson Univ. (United States); D. R. Holmes III, Mayo Clinic (United States)

Tracking and localization play a pivotal role in the design of an image guided surgery system. Knowing the position of a tool in the surgical field allows for placement of that tool into the image space. Inaccurate position measurement can lead to poor registration between tool and image spaces, while poor precision can lead to poor specificity of tool position. Accuracy and precision are innate properties of a tracker or tracking paradigm which while often cannot be corrected, can be compensated for.

Current techniques to assess tracker accuracy and precision are disparate and thus the measure made by one lab versus another may not mean the same thing. Previously, we have proposed a standardized technique, which can be applied to any novel tracker. This technique featured a easily reproducible rigid phantom, and a relatively simple method to analyze the data generated by sampling the positions on this phantom.

In this work we expand this technique as well as disseminate it to a second research group. In order to disseminate this work, a second phantom was created from the original CAD model. This second phantom was built using a new lighter weight material. A Northern Digital Instruments Aurora system at a second institution was tested, and processed. This allowed for a direct comparison between the systems as well as evaluation of the technique.

While the importance of accuracy and precision in the field of computer assisted and image-guided surgery are clear standardized measures of these quantities is currently lacking.

7964-85, Poster Session

Time-of-flight camera technology for augmented reality in computer-assisted interventions

S. Mersmann, M. Mueller, A. Seitel, Deutsches Krebsforschungszentrum (Germany); F. Arnegger, Ruprecht-Karls-Univ. Heidelberg (Germany); R. Tetzlaff, M. Baumhauer, Deutsches Krebsforschungszentrum (Germany); B. Schmied, Heidelberg School of Medicine (Germany); H. Meinzer, L. Maier-Hein, Deutsches Krebsforschungszentrum (Germany)

Augmented reality (AR) for enhancement of intra-operative images is gaining increasing interest in the field of navigated medical interventions. In this context, various imaging modalities such as ultrasound (US), C-Arm computed tomography (CT) and endoscopic images have been applied to acquire intra-operative information about the patient’s anatomy. The aim of this paper was to evaluate the potential of the novel Time-of-Flight (ToF) camera technology as means for markerless intra-operative registration. For this purpose, ToF range data and corresponding CT images were acquired from a set of explanted non-transplantable human and porcine organs equipped with a set of marker that served as targets. Based on a rigid matching of the surfaces generated from the ToF images with the organ surfaces generated from the CT data, the targets extracted from the planning images were superimposed on the 2D ToF intensity images, and the 2D target registration error (TRE) was computed as quality measure. Color video data of the same organs were further used to assess the 2D TRE for a previously proposed marker-based registration method. The ToF based registration showed promising accuracy yielding a mean TRE of 2.3 +- 1.2 mm compared to 0.5 +- 0.2 mm with the marker-based approach.

7964-86, Poster Session

Patient-specific blood flow simulation to improve intracranial aneurysm diagnosis

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We present a novel simulation system of blood flow through intracranial aneurysms including the interaction between blood lumen and vessel tissue. It provides the means to estimate rupture risks by calculating the distribution of pressure and shear stresses in the aneurysm, in order to support the planning of clinical interventions. So far, this has only been possible with commercial simulation packages originally targeted at industrial applications, whereas our implementation focuses on the intuitive integration into clinical workflow. Due to the time-critical nature of the application, we exploit most efficient state-of-the-art numerical methods and technologies together with high performance computing infrastructures (Austrian Grid). Our system builds a three-dimensional virtual replica of the patient’s cerebrovascular system from X-ray angiography images. The physician can then select a region of interest which is automatically transformed into a tetrahedral mesh. The differential equations for the blood flow and the wall elasticity are discretized on the mesh nodes via the Finite Element Method (FEM), and the resulting linear equation systems are handled by an Algebraic Multigrid (AMG) solver. At each time step, the wall displacement caused by the blood pressure is calculated and the fluid mesh is deformed accordingly. First comparisons of our simulation results with commercial simulation packages already show good medical relevance for diagnostic decision support.

7964-87, Poster Session

Augmented reality needle guidance improves facet joint injection training

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PURPOSE: The purpose of this study was to determine if medical trainees would benefit from augmented reality image overlay and laser guidance in learning how to set the correct orientation of a needle for percutaneous facet joint injection. METHODS: A total of 28 medical students were randomized into two groups: (1) The Overlay group received a training session of four insertions with image and laser overlay followed by two insertions with laser overlay only; (2) The Control group was trained by carrying out six freehand insertions. After the training session, needle trajectories of two facet joint injections without any guidance were recorded by an electromagnetic tracker and were analyzed. Number of successful needle placements, distance covered by needle tip inside the phantom and procedural time were measured to evaluate performance. RESULTS: Number of successful placements was significantly higher in the Overlay group compared to the Control group (85.7% vs. 57.1%, p = 0.038). Procedure time and distance covered inside phantom have both been found to be less in the Overlay group, although not significantly. CONCLUSION: Training with augmented reality image overlay and laser guidance improves the accuracy of facet joint injections in medical students learning image-guided facet joint needle placement.

7964-88, Poster Session

Effects of deflated lung's geometry simplifications on the biomechanical model of its tumor motion: a phantom study

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Deflated lung's geometry simplifications effects on the accuracy of biomechanical model used for its tumor motion prediction are investigated. This investigation is necessary to determine the highest degree of simplifications that can be incorporated in Finite Element (FE) model of a deflated lung without compromising its ability to predict tumor motion with reasonable accuracy. The simplifications involve neglecting the lung's airways in its FE model. Such simplification is important to avoid unnecessary complications and to pave the way for fast tumor location prediction during a lung tumor ablative procedure such as brachytherapy. One major factor, which may affect the accuracy of such ablative procedures, is tumor motion resulting from lung tissue deformation caused by respiration. Although the target lung is almost completely deflated during the procedure, tissue deformation remains an issue due to diaphragm contact forces during respiration. In this investigation several numerical experiments were conducted using different tumor and airway sizes and locations in conjunction with both elastic and hyperelastic material models. Sensitivity of the tumor's motion prediction accuracy to the geometry simplification was then presented as a function of airways' size relative to the tumor's size. FE analysis results obtained for both material models suggest that tumor displacements due to surface contact forces are not very sensitive to geometry simplification carried out by omitting airways with a size up to the tumor size.

7964-89, Poster Session

Creation of 3D digital anthropomorphic phantoms which model actual patient non-rigid body motion as determined from MRI and position tracking studies of volunteers

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Patient motion can cause artifacts which can lead to difficulty in interpretation. The purpose of this study is to create 3D digital anthropomorphic phantoms which model the location of the structures of the chest and upper abdomen of human volunteers undergoing a series of clinically relevant motions. The 3D anatomy is modeled using the XCAT phantom and based on MRI studies. The NURBS surfaces of the XCAT are interactively adapted to fit the MRI studies. A detailed XCAT phantom is first developed from an EKG triggered Navigator acquisition composed of sagittal slices with a 3 x 3 x 3 mm voxel dimension. Motion states are then acquired at breath-hold as sagittal slices with 9 mm gaps between them and the structures of the initial XCAT adapted to fit these different motion states. Simultaneous to MRI imaging the positions of multiple reflective markers on stretchy bands about the volunteer's chest and abdomen are optically tracked in 3D via stereo imaging. These phantoms with combined position tracking will be used to investigate both imaging-data-driven and motion-tracking strategies to estimate and correct for patient motion. Our initial application will be to cardiac-perfusion SPECT imaging where the XCAT phantoms will be used to create patient activity and attenuation distributions for each volunteer with corresponding motion tracking data from the markers on the body-surface. Monte Carlo methods will then be used to simulate SPECT acquisitions which will be used to evaluate various motion estimation and correction strategies.

7964-90, Poster Session

3D reconstruction of microvascular flow phantoms with hybrid image modalities

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Microvascular flow phantoms were built to aid the development of a hemodynamic simulation model for treating hepatocelluar carcinoma. The goal is to predict the blood flow routing for embolotherapy planning. Embolization is to deliver agents (e.g. microspheres) to the vicinity of the tumor to obstruct blood supply and nutrients to the tumor, targeting into 30 - 40 μm arterioles. Due to the size of the catheter, it has to release microspheres at an upper stream location, which may not localize the blocking effect. Accurate anatomical descriptions of microvasculature will help to conduct a reliable simulation and prepare a successful embolization strategy. Modern imaging devices can generate 3D reconstructions with ease. However, with a fixed detector size, larger field of view yields lower resolution. Clinical CT images can't be used to measure micro vessel dimensions, while micro-CT requires more acquisitions to reconstruct larger vessels. A multi-tiered, montage 3D reconstruction method with hybrid-modality imagery is devised to minimize the reconstruction effort. Regular CT is used for larger vessels and micro-CT is used for micro vessels. The montage approach aims to stitch up images with different resolutions and orientations. A resolution-adaptable 3D image registration is developed to assemble the images. We have created vessel phantoms that consist of several tiers of bifurcating polymer tubes in reducing diameters, down to 25 μm. No previous work of physical flow phantom has ventured into this small scale. Overlapping phantom images acquired from clinical CT and micro-CT are used to verify the image registration fidelity.

7964-91, Poster Session

A biomechanical liver model for intraoperative soft tissue registration

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Organ motion due to respiration and contact with surgical instruments can significantly degrade the accuracy of image guided surgery. In most applications the ensuing soft tissue deformations have to be compensated in order to register preoperative planning data to the patient. Biomechanical models can be employed to perform an accurate registration based on sparse intraoperative sensor data. Using elasticity theory, the approach can be formulated as a boundary value problem with displacement boundary conditions. In this paper, several models of the liver from the literature and a new simplified model are

evaluated with regards to their application to intraoperative soft tissue registration. We construct finite element models of a liver phantom using the different material laws. Thereafter, typical deformation pattern that occur during surgery are imposed by applying displacement boundary conditions. A comparative numerical study shows that the maximal registration error of all non-linear models stays below 1.1mm, while the linear model produces errors up to 3.9mm. It can be concluded that linear elastic models are not suitable for the registration of the liver and that a geometrically non-linear formulation has to be used. Although the stiffness parameters of the non-linear materials differ considerably, the calculated displacement fields are very similar. This suggests that a difficult patient-specific parameterization of the model might not be necessary for intraoperative soft tissue registration. We also demonstrate that the new simplified model achieves nearly the same registration accuracy as complex quasi-linear viscoelastic models.

7964-92, Poster Session

Approach-specific multi-grid anatomical modeling for neurosurgery simulation with Paraview

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This paper presents on-going work on multi-resolution sulcal-separable meshing for approach-specific neurosurgery simulation, in conjunction with the planned combination of two nonlinear biomechanics engines, based on multi-grid and Total Lagrangian Explicit Dynamics finite elements. TLEDs produce efficiencies through precomputations, feasible by expressing quantities in terms of undeformed coordinates, and through GPU acceleration. Multi-grid FE represent the anatomy at two or more levels of resolution, where the coarse level helps bring the finer level(s) into convergence. TLEDs require a time step to be proportional to the smallest edge of a mesh, so interactive use hinges on a sparse coarse-level representation. This coarse representation conflicts with the need of a simulation to account for small structures such as a pathology or critical tisues. The latter requirement imposes the need for a fine-level representation, i.e.: a multi-grid framework.

Two key points are to be made. First, the meshing approach must have explicit control over resolution. Second, the choice of neurosurgical approach is known ahead of time, based on the position of the pathology: frontal, pterional, trans-nasal, and so on. The planned surgical path, which is consistent with the choice of approach and can be specified by a series of user-selected points via ParaView, is used to define a subvolume of clinical interest, within some distance of the path and the target pathology. Restricted to this subvolume are the tetrahedralization of finer resolution, the representation of critical tissues, and warranted by the simulation, separability about one or more sulci at all mesh levels.

7964-93, Poster Session

3D shape decomposition and comparison for gallbladder modeling

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This paper presents an approach to gallbladder shape comparison by using 3D shape modeling and decomposition. The gallbladder models can be used for shape anomaly analysis and model comparison and selection in image guided robotic surgical training, especially for laparoscopic cholecystectomy simulation. The 3D shape of a gallbladder is first represented as a surface model, reconstructed from the contours segmented in CT data by a scheme of propagation based voxel learning and classification. To better extract the shape feature, the surface mesh is further down-sampled by a decimation filter and smoothed by a Taubin algorithm, followed by applying an advancing front algorithm to further enhance the regularity of the mesh. Multi-scale curvatures are then computed on the regularized mesh for the robust saliency landmark localization on the surface. The shape decomposition is proposed based on the saliency landmarks and the concavity, measured by the distance from the surface point to the convex hull. With a given tolerance the 3D shape can be decomposed and represented as 3D ellipsoids, which reveal the shape topology and anomaly of a gallbladder. A scheme based on the decomposed shape model is proposed for gallbladder shape comparison, which is used for model selection in image guided robotics assistive cholecystectomy training. We have collected 19 sets of abdominal CT scan data with gallbladders, some in normal shape and some shown in abnormal shapes. The experiments have shown that the comparison based on the decomposed shapes reveal the important topology features.

7964-94, Poster Session

Virtual simulation of the postsurgical cosmetic outcome in patients with pectus excavatum

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Pectus excavatum is the most common congenital deformity of the thoracic wall that, in a high percentage of cases, demands surgical correction. This deformity involves the sternum and the cartilages, being detected in the childhood and happens in 1:1000 births with male predominance of 4 for 1. The pectus excavatum can present moderate concave depressions with few millimeters to severe asymmetrical depressions with wide centimeters.

The surgical correction of this deformity is usually executed for the cosmetic improvement and prevention of psychological problems in the patient, not being usually associated to disfunctions cardio-pulmonary sufficiently serious that can affect the normal life of the patient. Since the initial report of minimal invasive repair of pectus excavatum in 1998, the technique described by Donald Nuss has gained world-wide acceptance and is gaining popularity for the repair of pectus excavatum (Nuss et al., 1998).

Once this is essentially a cosmetic problem, with serious psychological implications, it would be important the development of a software tool that could predict the patient postsurgical outcome. This kind of information would be valuable to the doctor, who could simulate the effect of placing the prosthesis in the patient, and to the patient, since it would reduce their fears regarding the surgical procedure, helping him to decide for the surgery.

This work proposes the development of software application, based on artificial neural network (ANN), able to predict the patient postsurgical outcome. It is expected that this application could be used as support to the medical diagnosis and decision.

7964-95, Poster Session

Intensity non-standardness affects computer recognition of anatomical structures

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Since MR image intensities do not possess a tissue specific numeric meaning, even in images acquired for the same subject, on the same scanner, for the same body region, by using the same pulse sequence,

it is important to transform the image scale into a standard intensity scale so that, for the same body region, intensities are similar. The lack of a standard image intensity scale in MRI leads to many difficulties in tissue characterizability, image display, and analysis, including image segmentation and registration. The influence of standardization on these tasks has been documented well; however, how intensity non-standardness may affect the automatic recognition of anatomical structures for image segmentation has not been studied. Motivated from the study that we previously presented in SPIE Medical Imaging Conference 2010 [1, 4], in this study, we analyze the effects of intensity standardization on anatomical object recognition. A set of 31 scenarios of multiple objects from the ankle complex included in the model, plus seven different realistic levels of non-standardness introduced are considered for evaluation. The experimental results imply that, intensity variation among scenes in an ensemble - a particular characteristic of the behavior of non-standardness - degrades object recognition performance.

7964-96, Poster Session

A comprehensive validation of patient-specific CFD simulations of cerebral aneurysm flow with virtual angiography

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Image-based computational fluid dynamics simulations (CFD) have been proposed to investigate the local hemodynamics inside human cerebral aneurysm. The knowledge of the computed three-dimensional flow fields can be used to assist for clinical risk assessment and treatment decision making.

However, the reliability of CFD for accurately representing the cerebral blood flow is difficult to assess due to the impossibility of ground truth measurements. A recently proposed virtual angiography method has been used to indirectly validate CFD results by comparing virtually constructed and clinically acquired angiograms. However, the existing validations lack of either patient-specific boundary conditions (BCs) required for CFD simulations or quantitative comparison method.

In this work, in order to achieve a comprehensive CFD validation, a simulation pipeline is built including image-based geometry reconstruction, CFD simulations solving the dynamics of blood flow and contrast agent (CA), and virtual angiograms generation. Specifically, in contrast to the previous studies, patient-specific blood flow rate obtained by transcranial color coded Doppler (TCCD) ultrasound is used to impose CFD BCs. In additional to the visual comparisons, quantitative measures are defined to thoroughly evaluate the correspondence between the virtual and clinical angiograms, and thus, the reliability of CFD simulation. Exemplarily, two patient cases are presented. Close similarities are found in terms of spatial and temporal variations of CA distribution between the simulated and clinical angiograms. Besides, for both patient cases, discrepancies of less than 15% are found for the relative root mean square errors (rRMSE) of time intensity curve (TIC) comparison from the selected characteristic position.

7964-97, Poster Session

Alternative statistical methods for bone atlas modeling

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One of the prominent applications or statistical atlases is anatomical modelling of bones. Bone atlases are typically built by collecting a set of sample bone shapes and then developing a model for representing any bone shape using the variation in the sample set. A new patient's bone shape can then be compared with the database using shape models derived from the examples in the atlas to carry out a diagnostic analysis. For such a procedure, the first step is to be able to model the shape of the new patient with respect to the shapes in the atlas.

However, shape data is often very high dimensional in nature. Thus, dimensional reduction techniques are often used to represent these shapes using a small set of coefficients for comparison. Dimensional reduction techniques however need to ensure that the loss of dimensionality does not contribute to loss of relevant information for comparison of shapes.

Traditional bone atlas modelling is carried out using linear methods such as Principal Components Analysis (PCA).2 Here, the atlas model consists of a a mean shape and principal modes representing the variation of shapes within the atlas. A new shape, which is a high dimensional data vector, is then described using this mean and a weighted combination of the principal modes of variation.

The use of alternate methods for modelling statistical atlases of anatomy has not been explored very much.

The area of multilinear modelling5 and manifold learning3 present new ways of modelling high dimensional data.

Although more computationally expensive than most linear methods, these methods can be useful for capturing variations in the data that are typically missed out by simple linear models. In this paper, we compare and contrast several linear, multilinear and nonlinear methods for bone atlas modelling.

7964-98, Poster Session

Accuracy assessment of an automatic image-based PET/CT registration for ultrasound-guided biopsies and ablations

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The multimodal fusion of spatially tracked real-time ultrasound (US) with a prior CT scan has demonstrated clinical utility, accuracy, and positive impact upon clinical outcomes when used for guidance during biopsy and radiofrequency ablation for the treatment of cancer. Additionally, the combination of CT-guided procedures with positron emission tomography (PET) may not only enhance navigation, but add valuable information regarding the specific location and volume of the targeted masses which may be invisible on CT and US. The accuracy of this fusion depends on reliable, reproducible registration methods between PET and CT. This can avoid extensive manual efforts to correct registration which can be long and tedious in an interventional setting. In this paper, we present a registration workflow for PET/CT/US fusion by analyzing various image metrics based on normalized mutual information and cross-correlation, using both rigid and affine transformations to automatically align PET and CT. Registration is performed between the CT component of the prior PET-CT and the intra-procedural CT scan used for navigation to maximize image congruence. We evaluate the accuracy of the PET/CT registration by computing fiducial and target registration errors using anatomical landmarks and lesion locations respectively. We also report differences to gold-standard manual alignment as well as the root mean square errors for CT/US fusion. Ten patients with prior PET/CT who underwent ablation or biopsy procedures were selected for this study. Studies show that optimal results were obtained using a cross-correlation based rigid registration with a TRE of 1.1 +/- 0.7 mm using a discrete graph-minimizing scheme. We demonstrate the feasibility of automated fusion of PET/CT and its suitability for multi-modality ultrasound guided navigation procedures.

7964-99, Poster Session

2D-3D registration using gradient-based MI for image guided surgery systems

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Registration of preoperative CT data to intra-operative video images is necessary not only to compare the outcome of the vocal fold after surgery with the pre-planned shape but also to provide the image guidance for fusion of all imaging modalities. We propose a 2D-3D registration method using gradient-based mutual information. The 3D CT scan is aligned to 2D endoscopic images by finding the corresponding viewpoint between the real camera for endoscopic images and the virtual camera for CT scans. Even though mutual information has been successfully used to register different imaging modalities, it is difficult to robustly register the CT rendered image to the endoscopic image due to varying light patterns and shape of the vocal fold. The proposed method calculates the mutual information in the gradient images as well as original images, assigning more weight to the high gradient regions. The proposed method can emphasize the effect of vocal fold and allow a robust matching regardless of the surface illumination. To find the viewpoint with maximum mutual information, a downhill simplex method is applied in a conditional multi-resolution scheme which leads to a less-sensitive result to local maxima. To validate the registration accuracy, we evaluated the sensitivity to initial viewpoint of preoperative CT. Experimental results showed that gradient-based mutual information provided robust matching not only for two identical images with different viewpoints but also for different images acquired before and after surgery. The results also showed that conditional multi-resolution scheme led to a more accurate registration than single-resolution.

7964-100, Poster Session

Fast intra-operative nonlinear registration of 3D-CT to tracked, selected 2D-ultrasound slices

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In navigated liver surgery it is an important task to align intra-operative data to pre-operative planning data. This work describes a method to register pre-operative 3D-CT-data to tracked intra-operative 2D US-slices. Instead of reconstructing a 3D-volume out of the two-dimensional US-slice sequence we directly apply the registration scheme to the 2D-slices. The advantage of this approach is manyfold. We circumvent the time consuming compounding process, we use only known information, and the complexity of the scheme reduces drastically. As the liver is a non-rigid organ, we apply non-linear techniques to take care of deformations occurring during the intervention. During the surgery, computing time is a crucial issue. As the complexity of the scheme is proportional to the number of acquired slices, we devise a scheme which starts out by selecting a few “key-slices” to be used in the non-linear registration scheme. This step is followed by multi-level/multi-scale strategies and fast optimization techniques. In this abstract we briefly describe the new method and show first convincing results.

7964-101, Poster Session

Automatic C-arm pose estimation via 2D/3D hybrid registration of a radiographic fiducial

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Motivation: In prostate brachytherapy, real-time dosimetry would be ideal to allow for a rapid evaluation of the implant quality intra¬-operatively. However, this would require an imaging system that is both real-time and which provides, via multiple C-arm fluoroscopy images, clear information describing the three-dimensional position of the seeds deposited within the prostate. Thus, accurate tracking of the C-arm poses proves to be of critical importance to the process. Methodology: We compute the pose of the C-arm relative to a stationary radiographic fiducial of known geometry by employing a hybrid registration framework. Firstly, by means of an ellipse segmentation algorithm and a 2D/3D feature based registration, we exploit known FTRAC geometry to recover an initial estimate of the C-arm pose. Using this estimate, we then initialize the intensity-based registration which in turn serves to recover an accurate estimation of the C-arm pose. Results: Ground-truth pose was established for each C-arm image using a published and clinically tested segmentation-based method. Using 169 clinical C-arm images, the average rotation and translation errors were 0.68° (std= 0.06°) and 0.64 mm (std= 0.24 mm). Conclusion: Fully automated C-arm pose estimation using a 2D/3D hybrid registration scheme was found to be sufficiently accurate and robust for clinical trials.

7964-102, Poster Session

A comparison of thin-plate splines with automatic correspondences and b-splines with uniform grids for multimodal prostate registration

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This paper provides a comparison of spline-based registration methods applied to register interventional Trans Rectal Ultrasound (TRUS) and pre-acquired Magnetic Resonance (MR) prostate images for needle guided prostate biopsy. B-splines and Thin-plate Splines (TPS) are the most prevalent spline-based approaches to achieve deformable registration. Pertaining to the strategic selection of correspondences for the TPS registration, we propose a novel and automatic method to generate correspondences in the MR and US prostate images. The method exploits the prostate geometry with the principal components of the segmented prostate as the underlying framework and involves a triangulation approach. The correspondences are generated with successive refinements and Normalized Mutual Information (NMI) is employed to determine the optimal number of correspondences required to achieve an acceptable TPS registration. B-spline registration with successive grid refinements are consecutively applied for a significant comparison of the impact of the strategically chosen correspondences on the TPS registration against the uniform B-spline control grids. The experimental results are validated on 4 patient datasets. Dice Similarity Coefficient (DSC) is used as a measure of the registration accuracy. Average DSC values of 0.97+/-0.01 and 0.95+/-0.03 are achieved for the TPS and B-spline registrations respectively. B-spline registration is observed to be more computationally expensive than the TPS registration with average execution times of 128.09+/-21.7 seconds and 62.83+/-32.77 seconds respectively for images with maximum width of 264 pixels and a maximum height of 211 pixels.

7964-103, Poster Session

Phantom validation for ultrasound to statistical shape model registration of human pelvis

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P. Abolmaesumi, Univ. of British Columbia (Canada)

Total Hip Replacement (THR) has become a common surgical procedure in recent years, due to the increase in the aging population with osteoarthritis in the hip joint. Localization of the pelvic anatomical coordinate system (PaCS) is a critical step in accurate placement of the femur prosthesis in the acetabulum in THR. Intra-operative ultrasound (US) imaging can provide a radiation-free navigation system for localization of the PaCS. However, US images are noisy and cannot provide any anatomical information beneath the bone surface due to the total reflection of US beam at the bone-soft tissue interface. Therefore, intra-operative US is proposed to be fused with pre-operative imaging or a statistical shape model (SSM) which contains the full pelvis anatomical shape. Here, we propose a multi-slice to volume intensity-based registration of the pelvic SSM to a sparse set of 2D US images in order to localize the PaCS in the US. In this registration technique, a set of 2D slices are extracted from the pelvic shape model, based on the approximate location and orientation of a corresponding 2D ultrasound image. The comparison of the shape model slices and ultrasound images is made possible by using an ultrasound simulation technique and a correlation-based similarity metric. We demonstrate the feasibility of our proposed approach in localizing the PaCS on four patient-based phantoms. The phantoms are made by rapid prototyping from segmented patient CT data and are covered with an agar-based gel mimicking human soft tissue. None of the test datasets are included in the SSM generation.

7964-104, Poster Session

3D non-rigid registration using surface and local salient features for transrectal ultrasound image-guided prostate biopsy

X. Yang, H. Akbari, L. Halig, B. Fei, Emory Univ. (United States)

We present a 3D non-rigid registration algorithm for the potential use in combining PET/CT and transrectal ultrasound (TRUS) images for targeted prostate biopsy. Our registration is a hybrid approach that simultaneously optimizes the similarities from point-based registration and volume overlap matching terms. The 3D registration is obtained by minimizing the distances of corresponding points at the surface and within the prostate and by maximizing the overlap ratio of the bladder neck on both images. The hybrid approach not only capture deformation at the prostate surface and internal landmarks but also the deformation at the bladder neck regions. The registration of the surface and internal landmarks uses a soft assignment and deterministic annealing process. The correspondences between the surface and internal landmarks are iteratively established in a fuzzy-to-deterministic approach. B-splines are used for generating a smooth non-rigid spatial transformation. Registration accuracy is established by comparing against manual defined calcification pairs. The root-mean-squared (RMS) difference between the reference and floating images was decreased by 62.6+/-9.1% after registration. The mean of target registration error (TRE) was 0.88+/-0.16 mm for all five patients. The experimental results demonstrate the robustness and accuracy of the 3D non-rigid registration algorithm.

7964-105, Poster Session

GPU accelerated registration of a statistical shape model of the lumbar spine to 3D ultrasound images

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We present a parallel implementation of a statistical shape model registration to 3D ultrasound images of the lumbar vertebrae (L2-L4). Covariance Matrix Adaptation Evolution Strategy (CMA-ES) optimization technique, along with Linear Correlation of Linear Combination (LC2) similarity metric have been used, to improve the robustness and capture range of the registration approach. Instantiation and ultrasound simulation have been implemented on a graphics processing unit for a faster registration. Phantom studies show a mean target registration error of 3.2 mm, while 80% of all the cases yield target registration error of below 3.5 mm.

7964-106, Poster Session

Anatomically-correct deformable colon phantom

J. A. Norris, M. D. Barton, B. J. Davis, J. Bieszczad, N. L. Meunier, N. W. Brown, D. B. Kynor, Creare Inc. (United States)

We describe a technique to build an anatomically realistic soft-walled colon phantom designed to provide realistic computed tomography (CT) images of the colon. The resulting phantom is highly realistic and can be readily deformed to provide a platform and for testing and evaluation of coregistration and polyp detection algorithms used in computed tomographic colonograpy (CTC) imaging. The phantom was constructed to replicate the shape of a human colon as depicted during CTC imaging. The three-dimensional air-filled colonic lumen is segmented and then replicated using stereolithography yielding a detailed rigid physical model. The rigid physical model includes large scale features (e.g., haustral folds and tenia coli bands), down to small scale features (e.g., a small pedunculated polyp). Since the rigid model represents the internal air-filled volume, a highly-pliable silicone polymer is painted onto the rigid model. This thin layer of silicone, when removed, becomes the colon wall. Small 3 mm diameter glass beads are affixed to the outer wall. These glass beads show up with high-intensity in CT scans and provide a ground truth for evaluating performance of algorithms designed to register prone and supine CTC data sets. After curing, the silicone colon wall is peeled off the rigid model. The resulting colon phantom is filled with air and submerged in a water bath. CT images and intraluminal fly-through reconstructions from CTC scans of the colon phantom are compared against patient data to demonstrate the ability of the phantom to simulate a human colon.

7964-107, Poster Session

Elastic image registration via rigid object motion induced deformation

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In this paper, we estimate the deformations induced on soft tissues by the rigid independent movements of hard objects and create an admixture of rigid and elastic adaptive image registration transformations. By automatically segmenting and independently estimating the movement of rigid objects in 3D images, we can maintain rigidity in bones and hard tissues while appropriately deforming soft tissues. We tested our algorithms on 20 pairs of 3D MRI datasets pertaining to a kinematic study of the flexibility of the ankle complex of normal feet as well as ankles affected by abnormalities in foot architecture and ligament injuries. The results show that elastic image registration via rigid object-induced deformation outperforms purely rigid and purely nonrigid approaches.

7964-108, Poster Session

Correspondenceless 3D-2D registration based on expectation conditional maximization

X. Kang, R. H. Taylor, A. Mehran, Y. Otake, The Johns Hopkins Univ. (United States); W. Yau, P. Cheung, Y. Hu, The Univ. of Hong Kong (Hong Kong, China)

3D-2D registration is a fundamental task in medical applications. The reprojection error in the objective function is generally defined as the distance between the points detected in the image and the projection of its counterpart on the 3D model. Due to the physics of the X-ray imaging, however, the point features in the image are indistinguishable, creating difficulties in establishing correspondences between 2D point features and the 3D model. Anatomical landmarks often cannot be located certainly in X-ray images and the corresponding 3D features may be ambiguously defined. Problems exist even when fiducials are used. For instance, several fiducials may have the same appearance; fiducials may be occluded or obscured by anatomy; and false fiducials may be introduced by intraoperative clutter in the images through detectors. This can even be true in contour-based 3D-2D registration: often the anatomy of interest is not easy to extract in the presence of intraoperative clutter and/or the imperfect contour detection leads to false and missing contour segments. Therefore, there is a need for a method that can estimate the transformation without known correspondence is needed. While a number of correspondenceless registration methods have been proposed, they either do not support perspective projection or have other special requirements, making them inappropriate for the scenario discussed in this paper. ICP-like methods can be easily trapped in local minima due to the binary assignment of one-to-one correspondence, making it sensitive to initialization.

We propose a method to achieve 3D-2D registration without known correspondences in a probability framework. The problem is modeled using a Gaussian mixture model and solved through the expectation conditional maximization. One-to-one correspondence is not crucial to our method. Taking fiducial-based registration as an example, the experiments will demonstrate that our method can obtain equally good registration under the conditions where undistinguishable fiducials were occluded or obscured by others and influenced by falsely detected fidcuials, even thought the one-to-one correspondence probabilities are not high for all points.

7964-109, Poster Session

OpenCL based machine learning labeling of biomedical datasets

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In this paper, we propose a two-stage labeling method of large biomedical datasets through a parallel approach in a single GPU. Diagnostic methods, structures volume measurements, and visualization systems are of major importance for surgery planning, intra-operative imaging and image-guided surgery. In all cases, to provide an automatic and interactive method to label or to tag different structures contained into input data becomes imperative. Several approaches to label or segment biomedical datasets has been proposed to discriminate different anatomical structures in an output tagged dataset. Among existing methods, supervised learning methods for segmentation have been devised to easily analyze biomedical datasets by a non-expert user. However, they still have some problems concerning practical application, such as slow learning and testing speeds. In addition, recent technological developments have led to widespread availability of multi-core CPUs and GPUs, as well as new software languages, such as NVIDIA's CUDA, and OpenCL, allowing to apply parallel programming paradigms in conventional personal computers.

Adaboost classifier is one of the most widely applied methods for labeling in the Machine Learning community. In a first stage, Adaboost trains a binary classifier from a set of pre-labeled samples described by a set of features. This binary classifier is defined as a weighted combination of weak classifiers. Each weak classifier is a simple decision function estimated on a single feature value. Then, at the testing stage, each weak classifier is independently applied on the features of a set of unlabeled samples.

In this work, we propose an alternative representation of the Adaboost binary classifier. We use this proposed representation to define a new GPU-based parallelized Adaboost testing stage using the OpenCL architecture.

We provide numerical experiments based on large available data sets and we compare our results to CPU-based strategies in terms of time and labeling speeds.

7964-110, Poster Session

Advanced level set segmentation of the right atrium in MR

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Atrial fibrillation is a common heart arrhythmia, and can be effectively treated with ablation. Ablation planning requires 3D models of the patient's left atrium (LA) and/or right atrium (RA), therefore an automatic segmentation procedure to retrieve these models is desirable. In this study, we investigate the use of advanced level set segmentation approaches to automatically segment RA in magnetic resonance angiographic (MRA) volume images. Low contrast to noise ratio makes the boundary between the RA and the nearby structures nearly indistinguishable. Therefore, pure data driven segmentation approaches such as watershed and ChanVese methods are bound to fail. Incorporating training shapes through PCA modeling to constrain the segmentation is one popular solution, and is also used in our segmentation framework. The shape parameters from PCA are optimized with a global histogram based energy model. However, since the shape parameters span a much smaller space, it can not capture fine details of the shape. Therefore, we employ a second refinement step after the shape based segmentation stage, which follows closely the recent work of localized appearance model based techniques. The local appearance model is established through a robust point tracking mechanism and is learned through landmarks embedded on the surface of training shapes. The key contribution of our work is the combination of a statistical shape prior and a localized appearance prior for level set segmentation of the right atrium from MRA. We test this two step segmentation framework on porcine RA to verify the algorithm.

7964-111, Poster Session

Automatic 3D segmentation of ultrasound images using atlas registration and statistical texture prior

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We are developing a molecular image-directed, 3D ultrasound-guided, targeted biopsy system for improved detection of prostate cancer. In this paper, we propose an automatic 3D segmentation method for transrectal ultrasound (TRUS) images, which is based on multi-atlas registration and statistical texture prior. The atlas database includes registered TRUS images from previous patients and their segmented prostate surfaces. Three orthogonal Gabor filter banks are used to extract texture features from each image in the database. Patient-specific Gabor features from the atlas database are used to train kernel support vector machines (KSVMs) and then to segment the prostate image from a new patient. The segmentation method was tested in data from 10 patients. The average surface distance between our and manual segmentation is 0.29 ± 0.08

mm with a maximum distance of 2.38 mm, indicating that the atlas-based automatic segmentation method works well and can be used for 3D ultrasound-guided prostate biopsy.

7964-112, Poster Session

Quantitative wound healing measurement and monitoring system based on an innovative 3D imaging system

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In this paper we present a novel, handheld three-dimensional (3D) imaging system (hardware and software) that is able to perform accurate 3D measurement and modeling of a wound and track its healing status over time. Accurate measurement and tracking of wound healing enables physicians to assess, document, improve, and individualize the treatment plan given to each wound patient. In current wound care practices, physicians often visually inspect or roughly measure the wound to evaluate the healing status. This is not an optimal practice because human vision lacks precision and consistency, and quantifying slow or subtle changes is very difficult. As a result, an instrument that quantifies both skin color and geometric shape variations would be particularly useful in helping clinicians assess healing status and judge the effect of hyperemia, hematoma, local inflammation, secondary infection, and tissue necrosis. Our handheld 3D imaging system has several unique advantages over traditional methods for monitoring wound care: (a) Non-contact measurement; (b) Fast and easy to use; (c) 50 um 3D accuracy; (d) 2D/3D Quantitative measurements;(e) Handheld device; and (f) Reasonable cost (<$1,000). This research program was supported by a NIH grant.

7964-113, Poster Session

A GPU based adaptive clutter filter implementation for ultrasonic color flow imaging

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In ultrasonic color flow imaging, clutter filter is very important for sufficiently suppressing the clutter signal originating from stationary or slowly moving tissue. In order to get the high filter performance, the projection initialized IIR filter or polynomial regression filter is usually used. There have very few literatures discussing the GPU based IIR filter or regression filter implementation. This paper presents a unified framework for efficiently implementing the projection initialized IIR filter and polynomial regression filter on modern GPU architecture. In the context of ultrasonic color flow imaging, we also give the down-mixing based adaptive filter and autocorrelation based flow estimator implementation using the same framework. The results show that we can get real-time processing speed by using a low cost GPU.

7964-114, Poster Session

Between developable surfaces and circular con splines: curved slices of 3D volumes

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The paper deals with the construction of splines composed of segments of developable surfaces. This family of surfaces is useful for the display without deformation of curved slices extracted from volumetric data.

Pottman and Leopoldseder discuss splines constructed with segments of circular cones, i.e. cones of revolution.

These are easy to develop on a flat surface but might be restrictive as far the types of slices that can be extracted from the volume.

On the other side of the spectrum Aumann and Fernanandez-Jambrina consider the construction of developable surfaces along arbitrary polynomial curves and polynomial splines but the techniques for the isometric flattening are computationally cumbersome, because they involve the computation of the geodesic curvature of a certain curve and the numerical solution of a differential equation.

We propose a midway process between the two above: construct developable splines with segments of quadratic cones. This is a larger family than the cones of revolution used by Pottman and Leopoldseder and has the additional advantage that they are easier to unfold than the general developable splines of Aumann and Fernanandez-Jambrina.

We show examples of the extraction of information from a dental volume.

7964-115, Poster Session

A unified framework for voxel classification and triangulation

J. S. H. Baxter, T. M. Peters, E. C. S. Chen, Robarts Research Institute (Canada)

Visualization of surfaces from volumetric data is an area of active research within the medical imaging community. Two techniques are often employed: direct volume rendering (DVR) and isosurface rendering (ISR). In DVR, a transfer function (TF) is used to map the raw data value to optical properties such as opacity and color. Common volume rendering technique includes ray-casting and texture mapping (among others). In ISR, voxels are classified by a surface classification function (CF), followed by fitting geometric primitives to the detected surfaces, and rendering the geometric primitives using the conventional computer graphics techniques. Common techniques for fitting geometric primitives to surfaces include Marching Cube (MC) and Constrained Elastic Surface Nets3 (CESN). In both DVR/ISR, the design and the implementation of the TF/CF functions is the integral aspect of the visualization as it affect the quality of the final rendition. In this paper, a unified framework for voxel classification and triangulation for surface generation from volumetric data is presented. The proposed voxel CF is 2D in nature by taking raw data value and the gradient as input. Higher dimensional CFs are possible within the proposed framework. The proposed triangulation method is based on CESN, with modifications to improve mesh quality. Given a 2D CF, our implementation is able to classify a large CT/MRI volume in near real-time, with triangulated mesh visualized only seconds afterwards. We demonstrated the proposed framework by comparing the resulted surface mesh against MC and CESN in an environment with low resolution data and limited accuracy classification using Hausdorff distance as mesh quality metric.

7964-116, Poster Session

An interactive ROI tool for DTI fiber tracking

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Fiber tracking is one of the clinically most well-established analysis techniques for Diffusion Tensor Imaging data (DTI). It facilitates the reconstruction of anatomically known white matter structures by tracing trajectories on the tensor field obtained from diffusion weighted MR images. A crucial step when using this technique is the placement and shape of regions-of-interest (ROIs) to identify the structures in question. Typically, free-hand contours or simple geometric shapes like rectangles are placed in regions, where a given structure can be identified using the color coded DTI representation. However, such approaches result in a high variability of the resulting tracts and usually require additional filtering and placement of multiple ROIs. Also, the generation of accurate ROIs using a free-hand tool requires a significant amount of interaction time. We present a method which allows for interactive generation of anatomically meaningful ROIs for DTI fiber tracking based on geometric

similarities of the underlying tensor field. The method works similar to the magic-wand tool known from image editing software tools to create reasonable, fully image based ROIs using a single mouse-click.

7964-117, Poster Session

SimITK: rapid ITK prototyping using the Simulink visual programming environment

A. W. L. Dickinson, P. Mousavi, Queen's Univ. (Canada); D. G. Gobbi, Atamai, Inc. (Canada); P. Abolmaesumi, The Univ. of British Columbia (Canada) and Queen's Univ. (Canada)

The Insight Segmentation and Registration Toolkit (ITK) is a long-established, software package used for image analysis, visualization, and image-guided surgery applications. This package is a collection of C++ libraries, that can pose usability problems for users without C++ programming experience. To bridge the gap between the programming complexities and the required learning curve of ITK, we present a higher-level visual programming environment that represents ITK methods and classes by wrapping them into 'blocks' within MATLAB's visual programming environment, Simulink. These blocks can be connected to form workflows: visual schematics that closely represent the structure of a C++ program. Due to the heavily C++ templated nature of ITK, direct interaction between Simulink and ITK requires an intermediary to convert their respective datatypes and allow intercommunication. We have developed a "Virtual Block" that serves as an intermediate wrapper around the ITK class and is responsible for resolving the templated datatypes used by ITK to native types used by Simulink. Presently, the wrapping procedure for SimITK is semi-automatic in that it requires XML descriptions of the ITK classes as a starting point, as this data is used to create all other necessary integration files. The generation of all source code and object code from the XML is done automatically by a CMake build script that yields Simulink blocks as the final result. An example 3D segmentation workflow using cranial-CT data as well as a 3D MR-to-CT registration workflow are presented as a proof-of-concept.

7964-118, Poster Session

Multidimensional transfer functions for effective visualization of streaming ultrasound and elasticity images

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The low-cost and minimum health risks associated with ultrasound (US) have made ultrasonic imaging a widely accepted method to perform diagnosis and image-guided procedures. Despite the existence of 3D ultrasound probes, most analysis and diagnostic procedures are done by studying the B-mode images. Currently, multiple ultrasound probes include 6-DOF sensors that can provide positioning information. Such tracking information can be used to reconstruct a 3D volume from a set of 2D US images. Recent advances in ultrasound imaging have also shown that, directly from the streaming radio frequency (RF) data, it is possible to obtain additional information of the anatomical region under consideration including the elasticity properties. This paper presents a generic framework that takes advantage of current graphics hardware to create a low-latency system to visualize streaming US data, while combining multiple tissue attributes into a single illustration. In particular, we introduce a framework that enables real-time reconstruction and interactive visualization of streaming data, while enhancing the illustration with elasticity information. The visualization module uses two dimensional transfer (2D TFs) functions to more effectively fuse and map B-mode and strain values into specific opacity and color values. On commodity hardware, our framework can simultaneously reconstruct, render, and provide user interaction at 15 fps. Preliminary studies with synthetic and phantom datasets show the advantages and effectiveness of our technique with ultrasound data. Additional results show how two-dimensional transfer functions can be used to more effectively identify, analyze and visualize lesions in US data.

7964-119, Poster Session

Efficient 3D rendering for Web-based medical imaging software: a proof of concept

D. Cantor-Rivera, R. Bartha, T. M. Peters, Robarts Research Institute (Canada)

Medical Imaging Software (MIS) found in research and in clinical practice, such as in Picture and Archiving Communication Systems (PACS) and Radiology Information Systems (RIS), has not been able to take full advantage of the Internet as a deployment platform. MIS is usually tightly coupled to algorithms that have substantial hardware and software requirements. Consequently, MIS is deployed on thick clients which usually leads project managers to allocate more resources during the deployment phase of the application than the resources that would be allocated if the application were deployed through a web interface. To minimize the costs associated with this scenario, many software providers use or develop plug-ins to provide the delivery platform (internet browser) with the features to load, interact and analyze medical images. Nevertheless there has not been a successful standard means to achieve this goal so far.

This paper presents a study of WebGL as an alternative to plug-in development for efficient rendering of 3D medical models and DICOM images. WebGL is a technology that enables the internet browser to have access to the local graphics hardware in a native fashion. Because it is based in OpenGL, a widely accepted graphic industry standard, WebGL is being implemented in most of the major commercial browsers.

After a discussion on the details of the technology, a series of experiments are presented to determine the operational boundaries in which WebGL is adequate for MIS. A comparison with current alternatives is also addressed. Finally conclusions and future work are discussed.

7964-120, Poster Session

Efficient ray casting with LF-Minmax map in CUDA

J. Choi, Catholic Univ. of America (United States)

Ray casting is the most frequently used algorithm in direct volume rendering for displaying medical data, although it is computationally very expensive. Recent hardware improvements have allowed ray casting to be used in real-time, however there is room for performance gains to take advantage of the recent development of general-purpose graphical processing units (GPGPU). Since the ray casting algorithm consists of a number of rays that determine pixel values for each pixel, each ray can be processed independently with others, which perfectly fits to the architecture of parallel processing. The purpose of this paper is to implement the volume ray casting with the Compute Unified Device Architecture (CUDA) C to obtain higher rendering performance. This paper applies hierarchical loose fitting (LF) minmax map for better performance. The experimental results show that the new algorithm is up to 15 times faster than the conventional CPU-based ray casting algorithm even in the laptop computer.

7964-121, Poster Session

An interactive exploded view generation using block-based re-rendering method

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In recent days, generating a cut-away display to observe specific regions

of volume becomes a research issue. These methods can be categorized into volume deformation and exploded view generation for volumetric objects.

In scientific visualization, volume deformation is most widely used to get image of deformed 3D volumetric object. In general, it is performed by modifying the direction of rays in volume ray-casting method. We call those a set of deformed ray as 3D deformation filter kernel. This kernel has the same size of original volume, and it should be made in preprocessing stage for modification of ray direction. Every voxel in the 3D filter kernel contains directions and specific scalar values to move specific positions. It consumes texture memories to store the 3D filter kernels. So, it is very hard, or even impossible to manipulate large volume due to GPU's limited memory space. To make a deforming filter kernel, we have to generate a 3D volume texture larger than the size of original volume. Since original volume is 8-bit grayscale data, while 3D filter kernel is composed of 3-floating point values. Also volume deformation has critical drawback that it cannot support various types of deformation and cannot recreate different deformation kernel in real-time. So, we take much time to recreate the 3D filter before rendering phase and to upload a huge 3D texture in rendering time.

Exploded view generations are methods to decompose a volume into several regions and move them to specific positions respectively to provide more wide view. Then recently, it mostly renders a volumetric scene with GPU ray-casting. It per-forms ray traversal only once in GPU's pixel shader. However, the exploded view generation method cannot be possible to perform in real-time since it has to apply different cutting rules and ordering constraints to volume. Also, the ordering constraints changes or varies while performing different exploded viewing. We propose interactive volume decomposition method that can produce and replace a number of sub-volumes, generate interactive cut-away operation. Our method can be applied to interactive surgical simulation and volume animation.

7964-34, Session 8

Automatic detection of contrast injection on fluoroscopy and angiography for image guided trans-catheter aortic valve implantations (TAVI)

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Presentation of detailed anatomical structures via 3-D models helps navigation and deployment of the prosthetic valve in TAVI procedures. Fast and automatic contrast detection in the aortic root on X-ray images facilitates a seamless workflow to utilize the 3-D models by triggering 2-D/3-D registration automatically when motion compensation is needed. In this paper, we propose a novel method for automatic detection of contrast injection in the aortic root on fluoroscopic and angiographic sequences. The proposed method is based on histogram analysis and likelihood ratio test, and is robust to variations in the background, the density and volume of the injected contrast, and the size of the aorta. The performance of the proposed algorithm was evaluated on 26 sequences from 5 patients and 3 clinical sites, with 16 out of 17 contrast injections correctly detected and zero false detection. The proposed method is of general form and can be extended for detection of contrast injection in other organs and/or applications.

7964-35, Session 8

A patient-specific visualization tool for comprehensive analysis of coronary CTA and perfusion MRI data

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Cardiac magnetic resonance imaging (CMR) and computed tomography angiography (CTA) are widely used to assess heart disease. CMR is used to measure the global and regional myocardial function and to evaluate the presence of ischemia; CTA is used for diagnosing coronary artery disease, such as coronary stenoses. Nowadays, the hemodynamic significance of coronary stenoses is determined subjectively by combining information on myocardial function with assumptions on coronary artery territories.

As the anatomy of coronary arteries varies greatly between individuals, we developed a patient-specific tool for relating CTA and perfusion CMR data. The anatomical and functional information extracted from CTA and CMR data are combined into a unique frame of reference. Our graphical user interface provides various options for visualization. In addition to the standard perfusion Bull's Eye Plot (BEP), it is possible to overlay a 2D projection of the coronary tree on the BEP, to add a 3D coronary tree model, and to add a 3D heart model. The perfusion BEP, the 3D-models, and the CTA data are also interactively linked.

Using the CMR and CTA data of 12 patients, our tool directly established a spatial correspondence between diseased coronary artery segments and myocardial regions with abnormal perfusion. The location of coronary stenoses and perfusion abnormalities were visualized jointly in 3D, thereby facilitating the study of the relationship between the anatomic causes of a blocked artery and the physiological effects on the myocardial perfusion.

This tool is expected to improve diagnosis and therapy planning in the management of early-stage coronary artery disease.

7964-36, Session 8

Incorporating a Gaussian model at the catheter tip for improved registration of preoperative surface models

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Accurate visualization and targeting of specific anatomic locations are key components for successful treatment in catheter based cardiac ablation therapy. In order to augment visualization tools such as bi-plane fluoroscopy and real-time ultrasound, recent work has focussed on registering detailed, patient-specific models into the procedure. Surface based techniques are a popular approach, however, challenges include sensitivity to both the number and as well as locations of selected surface points, thereby making registration accuracy dependent on operator experience as well as patient anatomy. In previous work, we proposed an approach for improving both registration accuracy and stability by incorporating points from the continuously tracked catheter tip into the registration algorithm. The catheter tip was modeled as a single location as reported by the magnetic tracking system. It is known, however, that there is some inherent error in magnetic tracking, thus, at any given time the reported location of the catheter tip is more accurately modeled as a Gaussian cloud. In this paper, we extend our previous work by modeling the catheter tip as a Gaussian cloud and demonstrate that this representation reduces registration error and increases stability as compared to using a single location for each sample.

7964-37, Session 8

Patient specific optimal catheter selection for right coronary artery

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During coronary artery angiography, a catheter is used to inject contrast dye into the coronary arteries. Due to the anatomical variation of the

aorta and the coronary arteries in different humans, one common catheter cannot be used for all patients. The cardiologists test different catheters for a patient and select the best catheter according to the patient's anatomy. This procedure is time consuming and there is a slight chance of cancer from excessive exposure to radiation. To overcome these problems, we propose a computer aided catheter selection procedure. In this paper we present our approach for patient specific optimal catheter selection for right coronary angiography. Our approach involves segmentation of aorta and coronary arteries, finding the centerline and computing the Curve Angle (CA) and Curve Length (CL) between aorta and coronary arteries. We then compute CA and CL of catheters and suggest the catheter with closest CA and CL to the aorta's and coronary arteries' CA and CL. This solution avoids testing of many catheters during catheterization. The cardiologist already gets the recommendation about the optimal catheter for the patient prior to the intervention.

7964-38, Session 8

Data fusion for catheter tracking using Kalman filtering: applications in robot-assisted catheter insertion

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X-ray image guided angioplasty is a minimally invasive procedure that involves the insertion of a catheter into a blood vessel to remove blockages to blood flow. There are several issues associated with conventional angioplasty which cause risks for the patient (damage to blood vessels, dislodging plaque, etc.) and difficulties for the clinician (X-ray exposure, fatigue, etc.). Autonomous or semi-autonomous robot-assisted catheter insertion is a solution that can reduce these problems substantially. To perform autonomous catheter insertion, closed-loop position control of the distal tip of the catheter is required during insertion. Therefore accurate real-time position feedback is needed for this purpose. We have developed a real-time image processing algorithm for catheter tip position tracking which has good performance, but is sensitive to X-ray image artifacts caused by bones and dense tissue. An electromagnetic tracking system (EMTS) is another modality that has also been used for catheter tip position tracking, but it is sensitive to external electromagnetic interference and ferromagnetic material. Combining the measurement data provided by both imaging and magnetic sensors can compensate for the deficiencies of each and can also improve the robustness of catheter tip position tracking. We have developed a Kalman filter based sensor fusion scheme to overcome deficiencies of both of these methods and create reliable real-time tracking of a catheter tip. Experiments have been performed by inserting a guide catheter in a realistic model of the vasculature. The method has been tested in the presence of occlusion in the X-ray images and also electromagnetic interference. Results have been validated against offline manual segmentation of the images in several experiments.

7964-39, Session 9

Real-time surface reconstruction from stereo endoscopic images for intraoperative registration

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Minimally invasive surgery (MIS) is a medically complex discipline that can heavily benefit from computer assistance. One way to assist the surgeon is to blend in useful information about the intervention into the surgical view using Augmented Reality (AR). This information can be obtained during preoperative planning and integrated into a patient-tailored model of the intervention. Due to soft tissue deformation, intraoperative sensor data such as endoscopic images has to be acquired and rigidly and non-rigidly registered with the preoperative model to adapt it to local changes. By extracting depth information from these images, we can build an intraoperative surface model of the surgical site that can be used for registration.

Here, we focus on a procedure that intraoperatively reconstructs the surface from stereo endoscopic images with millimeter accuracy in real-time. It deals with stereo camera calibration, pixel-based correspondence analysis, 3D reconstruction and point cloud meshing. Robustness and speed are evaluated with intraoperative images. Accuracy is investigated in a setting with different test images and compared with a reconstruction method that serves as ground truth. We also present the whole workflow where a surface is reconstructed while the endoscope is tracked via an optical tracking system. In this workflow, we combine the reconstructed surface model with a preoperative model by registering these two models using the tracking information. As preliminary result, we show an initial overlay between an intraoperative and a preoperative surface model that leads to a successful rigid registration between these two models.

7964-40, Session 9

3D surface reconstruction for laparoscopic computer-assisted interventions: comparison of state-of-the-art methods

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One of the main challenges related to computer-assisted laparoscopic surgery is the accurate 3D reconstruction of organ surfaces. Although many different methods have been proposed in this context, no standard approach has been established so far. This can, among others, be attributed to the fact that the different methods have not yet been evaluated on the same data. The aim of this paper is therefore to compare different types of state-of-the-art surface reconstruction methods on identical objects. For that purpose, surface data from a set of porcine organs as well as organ phantoms is acquired with five different cameras: a novel Time-of-Flight (ToF) endoscope, a standard ToF camera, a stereoscope, a HDTV endoscope, and a PAL endoscope. The resulting reconstructed partial organ surfaces are then compared to the corresponding ground truth shapes extracted from CT using a set of local and global distance metrics.

7964-41, Session 9

A real-time online video overlay navigation system for minimally invasive laparoscopic tumor resection

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The purpose of this paper is to present a detailed description of our real-time navigation system for computer assisted surgery. The system was developed with laparoscopic partial nephrectomies as a first application scenario. The main goal of the application is to enable tracking of a tumor position and orientation during surgery. Our system is based on ultrasound to CT registration and electromagnetic tracking. The basic idea is to process tracking information to generate an augmented reality (AR) visualization of a segmented tumor model in the video image of a laparoscopic camera. This was achieved by utilizing the three open source toolkits MITK, VTK and OpenCV, with MITK being the development basis. Our system enhances the surgeon's view of the intraoperative situs and therefore facilitates higher safety during surgery. So far we have applied our system in vitro with two phantom trials with a surgeon which yielded promising results.

7964-42, Session 9

Constructing spherical panoramas of a bladder phantom from endoscopic video using bundle adjustment

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The high recurrence rate of bladder cancer requires patients to undergo frequent surveillance screenings over their lifetime following initial diagnosis and resection. Our laboratory is developing panoramic stitching software that would compile several minutes of cystoscopic video into a single panoramic image, covering the entire bladder, for review by an urolgist at a later time or remote location. Global alignment of video frames is achieved by using a bundle adjuster that simultaneously recovers both the 3D structure of the bladder as well as the scope motion using only the video frames as input. The result of the algorithm is a complete 360° spherical panorama of the outer surface. The details of the software algorithms are presented here along with results from both a virtual cystoscopy as well from real endoscopic imaging of a bladder phantom. The software successfully stitched several hundred video frames into a single panoramic with subpixel accuracy and with no knowledge of the intrinsic camera properties, such as focal length and radial distortion. In the discussion, we outline future work in development of the software as well as identifying factors pertinent to clinical translation of this technology.

7964-43, Session 9

Comparison of two navigation system designs for flexible endoscopes using abdominal 3D ultrasound

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This paper describes a navigation system for flexible endoscopes equipped with ultrasound scan heads. For navigation and needle biopsy procedures it provides additional oblique slices from preoperative CT volumes which are displayed with the corresponding endoscopic US image. In contrast to similar systems an additional abdominal 3D ultrasound image is used to achieve the required registration. Two different approaches are compared: one method is based on direct inter-modal registration between abdominal 3D ultrasound and CT volume. The second method uses another 3D US scan taken preoperatively before the CT scan. Here, the CT is calibrated by means of an optical tracking system and the transformation between CT and the calibrated 3D US can be calculated without image registration. Before intervention, a pre-interventional 3D US is registered intramodal to the preoperative US. This second method invoked the more robust and accurate procedure. For experimental studies a phantom has been developed which consists of a plastic tube inside a water tank. For error evaluation small plastic spheres are added. First results give an overall error of 3.9 mm for the first method while the overall error for the intramodal method amounted to 3.1 mm.

7964-44, Session 9

Evaluation of electronic biopsy for clinical diagnosis in virtual colonoscopy

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Virtual colonoscopy provides techniques not available in optical colonoscopy, an exciting one being the ability to perform an electronic biopsy. An electronic biopsy image is created using ray-casting volume rendering of the CT data with a translucent transfer function mapping higher densities to red and lower densities to blue. The resulting image allows the physician to gain insight into the internal structure of polyps. Benign tissue and adenomas can be differentiated; the former will appear as homogeneously blue and the latter as irregular red structures. Although this technique is now commonly included with clinical systems and has been used successfully for computer aided detection, there has so far been no study to evaluate the effectiveness of a physician using electronic biopsy in determining the pathological state of a polyp. We present here such a study, wherein an experienced radiologist ranked polyps based on electronic biopsy alone per scan (supine and prone), as well as both combined. Our results show a correct identification 77% of the time using prone or supine images alone, and 80% accuracy using both. Using ROC analysis based on this study with one reader and a modest sample size, the combined score is not significantly higher than using a single electronic biopsy image alone. However, our analysis indicates a trend of superiority for the combined ranking that deserves a follow-up confirmatory study with a larger sample and more readers. The current study yields hope that an improved electronic biopsy technique could become a primary clinical diagnosis method.

7964-45, Session 10

Closed-form inverse kinematics for intra-operative mobile C-arm positioning with six degrees of freedom

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For trauma and orthopedic surgery, maneuvering a mobile C-arm X-ray device into a desired position in order to acquire the right picture is a routine task. The precision and ease of use of the C-arm positioning becomes even more important for more advanced imaging techniques as parallax-free X-ray image stitching, for example. Standard mobile C-arms have only five degrees of freedom (DOF), which definitely restricts their motions that have six DOF in 3D Cartesian space. We have proposed a method to model the kinematics of the mobile C-arm and operating table as an integrated 6DOF C-arm X-ray imaging system. This enables mobile C-arms to be positioned relative to the patient's table with six DOF in 3D Cartesian space. Moving mobile C-arms to a desired position and orientation requires finding the necessary joint values, which is an inverse kinematics problem. In this paper, we present closed-form solutions, i.e. analytic expressions, obtained in an algebraic way for the inverse kinematics problem of the 6DOF C-arm model. In addition, we implement a 6DOF C-arm system for interactively radiation-free C-arm positioning based on a continuous guidance from C-arm pose estimation. For this we employ a visual marker pattern attached under the operating table and a mobile C-arm system augmented by a video camera and mirror construction. In our experiment, repositioning C-arm to a pre-defined pose in a phantom study demonstrates the practicality and accuracy of our developed 6DOF C-arm system.

7964-46, Session 10

Spectral-based 2D/3D x-ray to CT image rigid registration

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We present a spectral-based method for the 2D/3D rigid registration of X-ray images to a CT scan. The method uses a Fourier-based representation to decompose the six rigid transformation parameters problem into a two-parameter out-of-plane rotation and a four-parameter in-plane transformation problems. Preoperatively, a set of Digitally Reconstructed Radiographs (DRR's) are generated offline from the CT in the expected in-plane location ranges of the fluoroscopic X-ray cameras. Each DRR is transformed into a camera in-plane invariant features space. Intraoperatively, a few 2D projections of the patient anatomy are acquired with a X-ray camera. Each projection is transformed into its in-plane invariant representation. The out-of-plane parameters are first computed by maximization of the Normalized Cross-Correlation between the invariant representations of the DRRs and the X-ray images. Then, the in-plane parameters are computed with the phase correlation method based on the Fourier-Mellin transform. Experimental results on publicly available data sets show that our method can robustly estimate the out-of-plane parameters with accuracy of 1.5 deg. in less than 1 sec. for out-of-plane rotations of 10 deg. or more, and perform the entire registration in less than 10 secs.

7964-47, Session 10

Intra-temporal facial nerve centerline segmentation for navigated temporal bone surgery

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Approaches through the temporal bone require surgeons to drill away bone to expose a target skull base lesion while evading vital structures contained within it, such as the sigmoid sinus, jugular bulb, and facial nerve. We hypothesize that an image guidance system that continuously calculates the distance towards these structures and warns if the surgeon drills too close, will aid in making optimal trans-temporal approaches. Contemporary image guidance machines are lacking two parts for such a system: A good method to segment the inhomogeneous and complexly curved facial nerve, and a distance feedback interface.

In this paper we concentrated on the facial nerve segmentation. We developed a new model-based segmentation method to delineate the intra-temporal facial nerve centerline from clinically available CT images of the temporal bone semi-automatically. The method's accuracy was evaluated in an experimental setting. Three neurosurgeons used it to segment 120 facial nerves, which were compared to the gold standard: manually segmented facial nerve centerlines.

On average our method delineates facial nerve centerlines with a maximum error of 0.42±0.22 mm (mean±standard deviation) compared to manual segmentations.

These results demonstrate that neurosurgeons can use the segmentation technique to adequately segment facial nerve centerlines. Next we can investigate whether integration of our method with an image guidance interface results in a system that adequately warns surgeons during temporal bone drilling, and effectively diminishes risks of iatrogenic facial nerve palsy.

7964-49, Session 10

Insertion of electrode array using percutaneous cochlear implantation technique: a cadaveric study

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Cochlear implantation is a surgical procedure for treating patients with hearing loss in which an electrode array is inserted into the cochlea. The traditional surgical approach requires drilling away a large portion of the bone behind the ear to provide anatomical reference and access to the cochlea. A minimally-invasive technique, called percutaneous cochlear implantation (PCI), has been proposed that involves drilling a linear path from the lateral skull to the cochlea avoiding vital structures and inserting the implant using that drilled path. The steps required to achieve PCI safely include: placing three bone-implanted markers surrounding the ear, obtaining a CT scan, planning a surgical path to the cochlea avoiding vital anatomy, designing and constructing a microstereotactic frame that mounts on the markers and constrains the drill to the planned path, affixing the frame on the markers, using it to drill to the cochlea, and inserting the electrode through the drilled path. We present in this paper a cadaveric study demonstrating the PCI technique on three temporal bone cadaveric specimens for inserting electrode array into the cochlea. A custom microtable, which is a type of microstereotactic frame that can be constructed in less than five minutes, was fabricated for each specimen and used to reach the cochlea. The insertion was successfully performed on all three specimens. Post-insertion CT scans confirm the correct placement of the electrodes inside the cochlea without any damage to the facial nerve.

7964-78, Session 10

Optimization of multi-image pose recovery of fluoroscope tracking (FTRAC) fiducial in an image-guided femoroplasty system

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We use C-arm fluoroscopy to acquire intraoperative images during percutaneous femoroplasty in order to estimate the 3-dimensional distribution of the injected augmentation material. To register these 2D X-ray images to 3D CT we have been utilizing a custom, optically-tracked fluoroscope tracking (FTRAC) fiducial. Previously, the pipeline for this registration has involved initial manual segmentation and intensity-based image registration. Through experiments with optically tracked targets, the average registration error from this established pipeline has been 1.4 mm. This paper describes several improvements to the pose recovery of the fluoroscope tracking (FTRAC) fiducial during 2D/3D registration in our image-guided surgical system for femoroplasty.

7964-50, Session 11

Single camera closed-form real-time needle trajectory tracking for ultrasound

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In ultrasound-guided needle insertion procedures, tracking of the needle relative to the ultrasound image is beneficial for needle trajectory planning and guidance. A single camera closed-form method is proposed for automatic real-time trajectory tracking with a low-cost camera mounted directly on the ultrasound transducer. The camera is calibrated

to the ultrasound image coordinates. By mounting the camera on the transducer, issues of visual obstruction are reduced and accuracy of tracking is increased compared to camera-tracking systems with a larger workspace. Compared to previous work with stereo cameras, a single camera further reduces cost, complexity and size, but requires a needle with known markings. The proposed solution uses the depth markings etched on many common needles (e.g. epidural needle). A fully automatic image processing method has been developed for real-time identification of the needle trajectory using a novel closed-form solution based on three identified markings and the camera's intrinsic calibration parameters. The trajectory of the needle relative to the ultrasound image is calculated and displayed. Validation compares the calculated intersection of the needle trajectory to the ultrasound image with the depiction of the actual needle intersection in the image. The overall error is 3.0 ± 2.6 mm for a low-cost 640×480 USB camera (ARTCAM-34MC).

7964-51, Session 11

Feature-based US to CT registration of the aortic root

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A feature-based registration was developed to align biplane and tracked ultrasound images of the aortic root with a preoperative CT volume. In percutaneous aortic valve replacement, a prosthetic valve is inserted into the aortic annulus via a catheter. Poor anatomical visualization of the aortic root region can result in incorrect positioning, leading to significant morbidity and mortality. Registration of pre-operative CT to transesophageal ultrasound and fluoroscopy images is a major step towards providing augmented image guidance for this procedure. The proposed registration approach uses an iterative closest point algorithm to register a surface mesh generated from CT to 3D US points reconstructed from a single biplane US acquisition, or multiple tracked US images. The use of a single simultaneous acquisition biplane image eliminates reconstruction error introduced by cardiac gating and TEE probe tracking, creating potential for real-time intra-operative registration. A simple initialization procedure is used to minimize changes to operating room workflow. The algorithm is tested on images acquired from excised porcine hearts. Results demonstrate a clinically acceptable accuracy of 2.6mm and 5mm for tracked US to CT and biplane US to CT registration respectively.

7964-52, Session 11

Improved validation platform for ultrasound-based monitoring of thermal ablation

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PURPOSE: Thermal ablation is a popular method in local cancer management; however it is extremely challenging to predict thermal changes in vivo. Ultrasound could be a convenient and inexpensive imaging modality for real-time monitoring of the ablation.However, the required advanced image processing algorithms need extensive validation. Our goal is to design and develop a reliable test-bed for validation of these monitoring algorithms. METHOD: Our team previously developed a test-bed, consisting of ablated tissue sample and fiducial lines embedded in tissue-mimicking gel. The gel block is imaged by ultrasound and sliced to acquire pathology images. Following fiducial localization in both image modalities, the pathology and US data were registered. Ground truth ablated region is retrieved from pathology images and compared to the result of the ultrasound-based processing in 3D space. We improved on this platform to resolve limitations that hindered its usage in a larger-scale validation study. A realistic simulator for evaluating and optimizing different line fiducial structures was implemented, and a new fiducial line structure was proposed. RESULTS: A new generation of test-bed was developed, with software that does not require lengthy manual data processing, and easier to maintain and extend. The new proposed fiducial configuration outperforms the previously used in terms of accuracy, fiducial visibility, and allowance of larger tissue samples. Simulation results show improvement in pose recovery accuracy using our proposed fiducial structure, reducing target registration error (TRE) by 34%. CONCLUSION: A new generation, practically usable validation test-bed was implemented for validation of ultrasound-based thermal ablation monitoring.

7964-53, Session 11

Toward robotic needle steering in lung biopsy: a tendon-actuated approach

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Needle tip dexterity is advantageous for transthoracic lung biopsies, which are presently performed with rigid, straight biopsy needles. By providing intraoperative compensation for trajectory error and lesion motion, tendon-driven biopsy needles may reduce procedure time and limit patient radiation exposure. Furthermore, as we show in this paper, it is possible to actuate tendon-driven needles using compact and inexpensive robotic devices. We present an automated system for transthoracic lung biopsies designed to insert and efficiently steer a commercial, tendon-driven continuum biopsy needle under CT guidance. We also describe benchtop validation experiments to evaluate targeting accuracy and total procedure time using the robotically-controlled biopsy system.

7964-54, Session 11

Visualization of motion fields and critical point estimation: determining condence metrics for 4D PET registration

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Non-rigid registration is an open-ended problem and hence rating the performance of an algorithm in absolute terms is challenging. In images belonging to modalities such as PET with high levels of correlated noise, intensity/gradient based registration methods are liable to incorrectly determine the transform in specific regions owing to the effects of noise. One of the readily recognizable signatures of an incorrect registration is the anomalous behavior of the transformation in a local neighborhood: we expect that the registration of images belonging to human subjects conform to physically acceptable motion patterns. The detection of regions where the transform obtained (post registration) is unrealistic is of importance, as it will help to evaluate the quality of the registration. We show (1) clinical datasets superimposed with the motion vectors to view global motion patterns (2) Color-maps of vector singularities to visualize motion together with a confidence measure (3) Visualization of critical points using glyphs to look at motion vectors with reference to the anatomical organ of interest. Physical appropriateness can thus be judged based on expected modes of deformation at different locations. Due to the complexity of non-rigid registration, it is essential to examine the results before application in a clinical setting. The suggested method allows the user to quickly identify critical points/singularities and visualize the motion locally in greater detail. Knowledge of these locations and a measure describing the degree of singularity can allow one to control and vary the regularization spatially.

7964-55, Session 11

Implementation of an interactive liver surgery planning system

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Liver tumor, one of the most wide-spread diseases, has a very high mortality in China. To improve success rates of liver surgeries and life qualities of such patients, we implement an interactive liver surgery planning system based on contrast-enhanced liver CT images. The system consists of five modules: pre-processing, segmentation, modeling, quantitative analysis and surgery simulation. The Graph Cuts method is utilized to automatically segment the liver based on an anatomical prior knowledge that liver is the biggest organ and has almost homogeneous gray value. The system supports users to build patient-specific liver segment and sub-segment models using interactive portal vein branch labeling, and to perform anatomical resection simulation. It also provides several tools to simulate atypical resection, including resection plane, sphere and curved surface. To match actual surgery resections well and simulate the process flexibly, we extend our work to develop a virtual scalpel model and simulate the scalpel movement in the hepatic tissue using multi-plane continuous resection. In addition, the quantitative analysis module makes it possible to assess the risk of a liver surgery. The preliminary results show that the system has the potential to offer an accurate 3D delineation of the liver anatomy, as well as the tumors' location in relation to vessels, and to facilitate liver resection surgeries. Furthermore, we are testing the system in a full-scale clinical trial.

Conference 7965: Biomedical Applications in Molecular, Structural, and Functional Imaging

Sunday-Wednesday 13-16 February 2011 • Part of Proceedings of SPIE Vol. 7965 Medical Imaging 2011: Biomedical Applications in Molecular, Structural, and Functional Imaging

7965-01, Session 1

Characteristics of voxel prediction power in full-brain Granger causality analysis of fMRI data

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It is well known that the brain is a complex interconnected dynamical system. Yet the most common techniques to analyze the functional neuroimaging data identify only brain regions that become “active” in response to a specific experimental condition. Of late, there has been a surge in interest in studying ``interactions” among brain regions.

The simplest approaches to model interactions among brain regions are based on the notion of “functional connectivity”. These approaches suffer from the problem of spurious connections due to confounding effects. The “effective connectivity” approaches, such as dynamic casual modeling and structural equations model alleviate this problem, but require a priori specification of regions of interest (ROIs) and experimental hypotheses. Granger causality analysis is a promising approach that does not have these limitations.

Due to the problem of dimensionality, most of the work in applying Granger causality to fMRI data has resorted to decreasing the size of data by either aggregating it into a small number of regions or by considering only pair-wise interactions among the voxels. We apply this technique to full-brain fMRI without any data aggregation. We circumvent the problem of dimensionality using sparse regression from machine learning. Using simulations, our earlier work demonstrated that the true model can be recovered by our approach.

In this paper, we analyze fMRI data from a simple finger-tapping experiment. We found that (1) a small number of voxels in the brain have very high prediction power; (2) these voxels occur in small sized clusters (of size 1-4 voxels) distributed throughout the brain; (3) albeit small, these clusters overlap with most of the clusters identified with the non-temporal General Linear Model (GLM); and (4) the method identifies clusters which, while not determined by the task and not detectable by GLM, still influence brain activity.

7965-02, Session 1

A methodology for dynamic functional connectivity

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Neuroimaging data analysis not only emphasizes the functional specification of brain units (neuron columns, recording sites, regions, etc), but also focuses on the massively parallel nature of distributed and interacting units that are hypothesized to process the functional task under investigation. Studying brain interactions leads to an emerging field: functional connectivity. Its objective is to capture the context-dependent processes that may lead to preferential recruitment of some brain units over others.

Our previous study proposed five measures to assess functional connectivity and have given promising results. However, these classical measures also have limitations. The main limitation is that these measures assume i) time courses which represent the neural electrical signals be stationary, and ii) the functional connectivity be the time-invariant over the entire time courses. Other limitations include a) they do not provide the directional information flow between brain units, and b) they are bivariate measures and could be potentially misleading when applied to multivariate structures.

This paper proposes a new approach to tackle the main limitation. A statistics reasoning shows that the short-length time course is more likely to be stationary than the long-length time course. Thus, the entire time course under investigation is divided into short segments with the proper length. Magnitude squared coherence (in spectrum domain) is computed to assess functional connectivity on these segments, hence, provides a dynamic measure of functional connectivity. The averaged magnitude squared coherence over the segments gives an overall measure of functional connectivity. This approach has been applied to several neuroimaging data which include autism rest status study, epilepsy data, and the motor data. The results and the interpretations / predictions are in good agreement.

As an extension to the time domain, Mutual coherence will be computed to assess functional connectivity, hence, provides an insight on directional information flow. By using grid computing, this approach will be extended from the bivariate to the multivariate.

7965-03, Session 1

Effective connectivity of neural pathways underlying disgust by multivariate Granger causality analysis

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The disgust system arises phylogenetically in response to danger to the internal milieu from pathogens and their toxic products. Functional imaging studies have demonstrated that a much wider range of neural structures was involved in triggering disgust reactions. However, less is understood regarding how and by what neural pathways these neural structures interact. To address this issue, we adopted an effective connectivity based analysis namely multivariate Granger causality approach to explore the causal interactions within these brain networks. Results presented that disgust can induce a much denser connectivity network in comparison with that of the neutral condition. Moreover, the anterior insula, having multiple casual interactions with limbic and subcortical areas, was implicated as a central hub in organizing multiple information processing in the disgust system.

7965-04, Session 1

The neural correlates of face processing and Chinese character processing in children

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It is well known that adults are experts at processing words and faces. Accordingly, adult research has identified two neural expertise systems involved in word processing and face processing within the fusiform gyrus, respectively, namely the visual word form area (VWFA) and fusiform face area (FFA). The present study used fMRI to explore whether similar differentiations exist for the FFA and VWFA in 10~11-aged children, by comparing the activation between faces, Chinese characters, and common objects. Our study identified adult-like Chinese character-preferential activation and common object-preferential activation in 10~11-aged children, especially with the fusiform gyrus, while fail to reveal a consistent region showing preferential response to faces. An inspection of individual activation of faces relative to Chinese characters and common objects revealed adults-like FFA in some of children,

indicating that the absence of face-preferential activation at the group level may be mainly due to the considerable variability in the magnitude and locus of individual face-preferential activation. Our finds suggested that the Chinese character-preferential regions and common object-preferential regions within the fusiform gyrus may be formed earlier than that of faces. Especially, though the VWFA and FFA are both related to visual expertise, our findings indicated that the VWFA can be formed only through a 3~4-years' schooling; in contrast the formation of FFA appear to undergo a more prolonged development before it reaches the adult level.

7965-05, Session 1

Learn the effective connectivity pattern of attention networks: a resting functional MRI and Bayesian network study

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Task-based neuroimaging studies revealed that different attention operations were carried out by the functional interaction and cooperation between two attention systems: the dorsal attention network (DAN) and the ventral attention network (VAN), which were respectively involved in the "top-down" endogenous attention orienting and the "bottom-up" exogenous attention reorienting process. Recent focused resting functional MRI (fMRI) studies have found the two attention systems were inherently organized in the human brain regardless of whether or not the attention process were required. But how the two attention systems interact with each other in the absence of task is yet to be investigated. In this study, we first separated the DAN and VAN by applying the group independent component analysis (ICA) to the resting fMRI data acquired from 12 healthy young subjects, then applied the Gaussian Bayesian network (BN) learning approach to explore the plausible effective connectivity pattern of the two attention systems. It was found regions from the same attention network were strongly interdependent, and all the connections were located in the information flow from VAN to DAN, which suggested that an orderly functional interactions and information exchanges between the two attention networks existed in the intrinsic spontaneous brain activity, and the inherent connections might benefit the efficient cognitive process between DAN and VAN, such as the "top-down" and "bottom-up" reciprocal interaction when attention-related tasks were involved.

7965-06, Session 2

Automatic localization of bifurcations and vessel crossings in digital fundus photographs using location regression

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Parameters extracted from the vasculature on the retina are correlated with various conditions such as diabetic retinopathy and cardiovascular diseases such as stroke. Segmentation of the vasculature on the retina has been a topic that has received much attention in the literature over the past decade. Analysis of the segmentation result, however, has only received limited attention with most works describing methods to accurately measure the width of the vessels. Analyzing the connectedness of the vascular network is an important step towards the characterization of the complete vascular tree. The retinal vascular tree, from an image interpretation point of view, originates at the optic disc and spreads out over the retina. The tree bifurcates and the vessels also cross each other. The points where this happens form the key to determining the connectedness of the complete tree. We present a supervised method to detect the bifurcations and crossing points of the vasculature of the retina. The method uses features extracted from the vasculature as well as the image in a location regression approach to find those locations of the segmented vascular tree where the bifurcation or crossing occurs (from here, POI, points of interest). We evaluate the method on the publicly available DRIVE database in which an ophthalmologist has marked the POI.

7965-07, Session 2

Normal and keratoconic corneal epithelial thickness mapping using Fourier-domain optical coherence tomography

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Purpose:: The detection of early-stage keratoconus is one of the most important safety issues in screening candidates for corneal refractive surgeries. The corneal epithelial thickness in normal and keratoconic eyes was mapped with optical coherence tomography (OCT). We propose to use epithelial thickness maps to assist the diagnosis of keratoconus.

Methods: A Fourier-domain OCT system capable of acquiring 26,000 axial-scans per second was used. It has an axial resolution of 5μm in cornea. A pachymetry scan pattern (8 radials, 1024 axial-scans each, 6mm diameter, repeat 3 times) centered at the pupil center was used to image the cornea. The 3 repeated radial scans on each meridian were registered and averaged to increase the signal-to-noise ratio. Then the anterior corneal, posterior corneal and epithelial boundaries were segmented automatically with a computer algorithm by increased signal intensity at corresponding boundaries. The epithelial thickness map was generated by interpolating epithelial thickness profile calculated from each meridian. Normal and keratoconic eyes (24 eyes each) were scanned 3 times.

Results: The central epithelial thickness in normal eyes was thicker than those of keratoconic eyes (mean difference 2.1 μm, t-test p=0.05). The epithelium was thinner superiorly than inferiorly in normal eyes (mean difference -1.4±1.1μm, p<0.001) while thicker superiorly than inferiorly in keratoconic eyes (2.0±4.1 μm, p=0.02).

Conclusions: High-resolution high-speed FD-OCT is able to map the corneal epithelial thickness in normal and keratoconic eyes with excellent reproducibility. The epithelial thickness asymmetry pattern may be useful to identify keratoconic corneas from the normal.

7965-08, Session 2

Estimation of blood flow rate using intensity signal in optical coherence tomography

N. Mohan, B. J. Vakoc, Massachusetts General Hospital (United States)

We present techniques for in vivo estimation of blood flow rates using optical coherence tomography (OCT). The flow rate information is derived from the temporal modulations in the OCT intensity signal. Customized, model-based processing algorithms based on spectral estimation with non-uniform sampling are employed to extract flow from a small set of measurements acquired at each location. By spacing these measurements non-uniformly in time, the approaches are sensitive to a wide range of flow velocities while limiting the total number of measurements required, thereby providing an algorithmic basis for wide-field and comprehensive mapping of flow in vascular networks in reasonable imaging times. Specifically, we have employed autoregressive (AR)- and principal component analysis (PCA)-based methods. The implementation of both these techniques was adapted to work with non-uniformly sampled data. We first tested the performance of these techniques on the simulated OCT signal in the presence of moving scatterers. We compared the performance over different sampling patterns, number of samples and signal-to-noise ratio (SNR). To verify the performance of the techniques on the experimental data we acquired OCT images of intralipid phantom flowing at different rates. The flow rates were estimated using the AR and the PCA techniques at

different locations in the phantom. Finally we applied the aforementioned techniques to measure the flow rates in the blood vessels in the mouse ear and compared with Doppler-based approaches.

7965-09, Session 2

Deconvolution of dynamic dual photon microscopy images of cerebral microvasculature to assess the hemodynamic status of the brain

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Assessing the hemodynamic status of the brain and its variations in various situations are required to understand the local cerebral circulatory mechanisms. Dynamic contrast enhanced imaging of cerebral microvasculature provides information that can be used in understanding physiology of cerebral diseases. Bolus tracking is a technique that can be used to extract characteristic parameters that quantify local cerebral blood flow. However, post-processing of the data is needed to segment the FOV and to perform Deconvolution to remove the effects of input bolus profile and the path it travels to reach the imaging window. Finding the arterial input function (AIF) and dealing with the ill-posedness of deconvolution system make this process difficult. We propose using ICA to segment the FOV and to extract a local AIF as well as the venous output function that is required for deconvolution. This also helps to stabilize the system as ICA suppresses noise efficiently. Tikhoniv regularization (with L-curve analysis to find the best regularization parameter) is used to make the system stable and solve the problem. We have acquired dynamic 2PLSM images of a rat brain in two conditions (when the animal is at rest and when it is stimulated) and performed deconvolution. The experimental along with the simulation studies provided promising results that demonstrate the feasibility and importance of performing deconvolution.

7965-10, Session 2

Three-dimensional multi bioluminescent sources reconstruction based on adaptive finite element method

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Among many optical molecular imaging modalities, bioluminesent imaging (BLI) has more and more wide application in tumor detection and evaluation of pharmcodynamics, toxicity, pharmacokinetics because of its noninvasive molecular and cellular level detection ability, high sensitivity and low cost in comparison with other imaging technologies. However, BLI can not present the accurate location and intensity of the inner bioluminescence sources such as in the bone, liver or lung etc. Bioluminescent tomography (BLT) shows its advantage in determining the bioluminescence source distribution inside a small animal or phantom. Considering the deficiency of two-dimensional imaging modality, we developed three-dimensional tomography to reconstruct the information of the bioluminescence source distribution in transgenic mOC-Luc mice bone with theboudary measured data. In this paper, to study the osteocalcin (OC) accumulation in transgenic mOC-Luc mice bone, a BLT reconstruction method based on multilevel adaptive finite element (FEM) algorithm was used for localizing and quantifying multi bioluminescence sources. Optical and anatomical information of the tissues are incorporated as a priori knowledge in this method, which can reduce the ill-posedness of BLT. The data was acquired by the dual modality BLT and Micro CT prototype system that was developed by us. Through temperature control, time compensation and absolute intensity calibration, a relative accuracy intensity can be calculated. The location of the OC accumulation was reconstructed, which was coherrent with the principle of bone differentiation. This result also was testified by ex vivo experiment in the black 96-plate well using the BLI system and the chemiluminescence apparatus.

7965-11, Session 2

In vivo heterogeneous tomographic bioluminescence imaging via a higher-order approximation forward model

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In vivo bioluminescence imaging (BLI) has played a more and more important role in biomedical research of small animals. Tomographic bioluminescence imaging further translates the BLI optical information into three-dimensional bioluminescent source distribution, which could greatly facilitate applications in related studies. Although the diffusion approximation (DA) is one of the most widely-used forward models, higher-order approximations are still needed for in vivo small animal imaging. In this work, as a relatively accurate and higher-order approximation theory, a simplified spherical harmonics approximation (SPN) is applied for heterogeneous tomographic bioluminescence imaging in vivo. Heterogeneous in vivo experimental reconstructions via the higher-order approximation model demonstrate higher tomographic imaging quality, which is shown the capability for practical biomedical tomographic imaging applications.

7965-12, Session 3

Image-guided prostate sectioning supporting registration of graded cancerous foci from digital histopathology images to in vivo MRI: an interactive visualization tool

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Prostate cancer is the most common non-cutaneous cancer in men: in 2010, in Canada and the United States, over 240,000 men will be diagnosed with prostate cancer and over 36,000 will die from it. Personalized treatment of prostate cancer would be enhanced by an assessment of cancer stage and grade from imaging, the validation of which requires the accurate co-registration of in vivo images with a gold standard for stage and grade established by histopathology. This problem is challenging due to imaging- and tissue processing-induced deformations, and due to the 5 mm spacing between digital histopathology images. Based on the observation that careful orientation of specimen slicing simplifies the registration problem, we present a visualization tool supporting an image-guided approach enabling the acquisition of histopathology images parallel to the in vivo imaging planes. The tool is based on the use of a tracked probe and provides interactive 3D guidance for (1) landmark-based imaging-to-specimen registration for cutting plane specification, (2) verification of anatomic concordance between registered images and specimen, and (3) positioning the tracked probe within the desired slicing plane for guiding the insertion of marker pins orienting the specimen in a slotted forceps for slicing. This tool decreases imaging-to-specimen landmark alignment error by 62%, and decreases the time required to mark the slicing plane on the specimen by 47%. Preliminary results from our method demonstrate the alignment of regions suspicious for cancer on T2w MRI with confirmed cancer foci on histopathology, and we calculate a sub-millimeter in-plane target registration error.

7965-13, Session 3

Mouse whole-body organ mapping by non-rigid registration approach

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Small animal imaging is increasingly used as a pre-clinical tool to identify new imaging agents, or assess effectiveness of therapy using micro-CT and Position Emission Tomography (PET) images in vivo. A very challenging task is small animal image registration and segmentation. Whole body organ registration is an important step to map organs from an atlas to any new data before a further image analysis step. In this paper, we propose a novel framework for mouse whole-body organ mapping by non-rigid registration method we developed. An improved 3D shape context based non-rigid registration method is applied for mouse whole-body skeleton registration and lung surface registration. A geodesic path based non-rigid registration method is proposed for mouse torso skin registration. Experiments were performed to test the methods on lung and skin surface registration. A preliminary whole-body organ mapping experiment was performed on three target data and four selected organs were compared with the manual outlining results by a biologist. The applicability and robust of the proposed method have been demonstrated. The registration errors were discussed and a future improvement was proposed.

7965-14, Session 3

Affine invariant parameterization to assess local shape in abdominal organs

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We present a novel method for three-dimensional (3D) shape parameterization. The approach is affine invariant and is applied to comparing local shape across abdominal organs. The inherent structure of the abdominal organs is used to generate a regular sampling of the organ's surface. 'Planar-convexity' is defined for a general 3D closed object as the property that there exists a set of parallel planes which cover the 3D space such that every intersection of a plane with the object is a singular closed planar curve. We show that this parameterization, combined with the 3D analogue of a 2D shape descriptor successfully shown to be invariant under affine transformations and noise, can be effectively used to compare features of two closed 3D surfaces point-to-point. The technique avoids common problems with the parameterization of concave surfaces and shows great potential for analyzing and improving the automatic modeling and segmentation of abdominal organs.

7965-15, Session 3

MRI-based quantification of duchenne muscular dystrophy in a canine model

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Duchenne muscular dystrophy (DMD) is a progressive and fatal X-linked disease caused by mutations in the DMD gene. Magnetic resonance imaging (MRI) has shown potential to provide non-invasive and objective biomarkers for monitoring disease progression and therapeutic effect in DMD. In this paper, we propose a semi-automated scheme to quantify MRI features of golden retriever muscular dystrophy (GRMD), a canine model of DMD. Our method was applied to a natural history data set and a hydrodynamic perfusion data set. The scheme is composed of three modules: preprocessing, muscle segmentation, and feature analysis. The preprocessing module includes: image smoothing, calculation of T2 maps, spatial registration of T2 weighted (T2WI) images, T2 weighted fat suppressed (T2FS) images, and T2 maps, and intensity calibration of T2WI and T2FS images. We then manually segment six pelvic limb muscles. For each of the segmented muscles, we finally automatically measure volume and intensity statistics of the T2 water maps (calibrated T2FS images) and T2 maps. For the natural history study, our results showed that four of six muscles in affected dogs have smaller volume and all had higher mean intensity in image maps as compared to normal dogs. These results were consistent with pathologic changes seen in the GRMD model. For the perfusion study, the muscle volume and T2 water maps intensities were significantly increased in the post-perfusion study as compared to pre-perfusion, as predicted. We conclude that our scheme successfully performs quantitative analysis of histologically validated muscle MRI features of GRMD.

7965-16, Session 3

Toward understanding the complex mechanisms behind breast thermography: an overview for comprehensive numerical study

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The abnormal thermogram has been shown to be a reliable indicator of a high risk of breast cancer. Nevertheless, a major weakness of current infrared breast thermography is its poor sensitivity for deeper tumors. Numerical modeling for breast thermography provides an effective tool to investigate the complex relationships between the breast thermal behaviors and the underlying pathophysiological conditions. We have developed a set of new modeling techniques to take into account some subtle factors that were usually ignored in previous studies, such as the gravity-induced elastic deformations of the breast, the nonlinear elasticity of soft tissues, and the dynamic behavior of the thermogram. Conventional "forward problem" modeling cannot be used directly to improve the tumor detectability, however, because the underlying tissue thermal properties are generally unknown. Therefore, we propose an "inverse problem" modeling technique that aims to estimate the tissue thermal properties from the breast surface thermogram. Our data suggest that the estimation of the tumor-induced thermal contrast can be improved significantly by using the proposed inverse problem solving techniques to provide the individual-specific thermal background, especially for deeper tumors. We expect the proposed new methods, taken together, to provide a stronger foundation for, and greater specificity and precision in, thermographic diagnosis, and treatment, of breast cancer.

7965-17, Session 4

Micro-CT characterization of human trabecular bone in osteogenesis imperfecta

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Osteogenesis imperfecta (OI) is a rare genetic syndrome affecting collagen synthesis and assembly. Its symptoms are numerous and vary in severity. However, common problems include bone fragility, reduced stature, and progressive spine and long bone deformities. Because of the small size and paucity of human specimens, there is a lack of biomechanical data for OI bone. To date, OI literature has focused on histomorphometric analyses, which rely on assumptions to extrapolate 3-D properties. In this study, a μCT system was used to directly measure trabecular properties in OI bone such as bone volume fraction (BV/TV), bone surface fraction (BS/BV), trabecular thickness (Tb.Th), number (Tb.N), spacing (Tb.Sp), and connectivity. In agreement with previous findings for healthy trabecular bone, our surface renderings of OI bone showed a predominately plate-like structure. Patients with a known history of bone augmenting drug therapy exhibited increases in BS/BV, Tb.N, and connectivity. These elevated parameters translated to the largest sources of inter-subject variability. Overall, results for the trabecular indices were consistently higher than those reported in a previous histomorphometric study on OI bone from the iliac crest. However, these differences could be attributed to any number of factors including differing specimen collection sites, drug therapies, and assumptions used in histomorphometry. Nevertheless, the μCT approach performed in this study is an attractive technique for OI bone assessment.

7965-18, Session 4

3D visualization and quantification of bone and teeth mineralization for the study of osteo/dentinogenesis in mice models

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Research on bone and teeth mineralization in animal models is critical for understanding human pathologies. Genetically modified mice represent highly valuable models for the study of osteo/dentinogenesis defects and osteoporosis. Current investigations on mice dental and skeletal phenotype use destructive and time consuming methods such as histology and scanning microscopy. Micro-CT imaging is quicker and provides high resolution qualitative phenotypic description. However reliable quantification of mineralization processes in mouse bone and teeth are still lacking. We have established novel CT imaging-based software for accurate qualitative and quantitative analysis of mouse mandibular bone and molars.

Data were obtained from mandibles of mice lacking the Fibromodulin gene which is involved in mineralization processes. Mandibles were imaged with a micro-CT originally devoted to industrial applications (Viscom, X8060 NDT). 3D advanced visualization was performed using the VoxBox software (UsefulProgress) with ray casting algorithms. Comparison between control and defective mice mandibles was made by applying the same transfer function for each 3D data, thus allowing to detect shape, colour and density discrepencies. The 2D images of transverse slices of mandible and teeth were similar and even more accurate than those obtained with scanning electron microscopy. Image processing of the molars allowed the 3D reconstruction of the pulp chamber, providing a unique tool for the quantitative evaluation of dentinogenesis.

This new method is highly powerful for the study of oro-facial mineralizations defects in mice models, complementary and even competitive to current histological and scanning microscopy appoaches.

7965-19, Session 4

Structure based classification of micro-CT images of human trabecular bone using local Minkowski functionals

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In this study we perform a structure characterization of the isotropic micro-CT image data using local Minkowski functionals (MF). 201 cylindrical trabecular bone specimens (diameter 8 mm and length 10 mm) were harvested from different skeletal sites (50 thoracic vertebrae, 18 calcaneous, 51 lumbar vertebrae, 28 femoral neck, 29 distal radius, and 25 trochanter) with an 8 mm inner diameter drill. Micro-CT images with isotropic spatial resolution of 26 x 26 x 26 microns were acquired. The sample has a bone fraction in the range [0.03,0.065]. Here, local MF are only evaluated for a characteristic scale of the network, namely for the mean trabecular spacing. Thus, we expect to obtain an optimal contrast between MF values for the different substructures (rods, plates, dense regions, etc). We apply a hierarchical clustering algorithm, to divide the sample into clusters according to the structural content of the specimens as rendered by the Euler characteristics. We use a symmetric form of the Kullback-Leibler entropy as a dissimilarity measure and the hierarchical tree is generated using the complete linkage method. The clusters show some interesting specific structural features, like compact, perforated, and fragmented structures. The contribution of the different skeletal sites indicates some variability due to intrinsic structural differences of the specific skeletal site. Since the MF are isotropic topological measures, it is expected that a similar approach based on measures sensitive to anisotropy reveal additional structural features. This method is not restricted to the use of the Euler characteristics but other local measures of structure can also be applied.

7965-20, Session 4

Detecting metastasis of gastric carcinoma using high-resolution micro-CT system: in vivo small animal study

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Immunocytochemical and immunofluorescence staining are used for identifying the characteristics of metastasis in traditional ways. Micro-computed tomography (CT) is a useful tool for monitoring and longitudinal imaging of tumor in small animal in vivo. In present study, we evaluated the feasibility of the detection for metastasis of gastric carcinoma by high-resolution micro-CT system with omnipaque accumulative enhancement method in the organs. Firstly, a high-resolution micro-CT ZKKS-MCT-sharp micro-CT was developed by our research group and Guangzhou Zhongke Kaisheng Medical Technology Co., Ltd. Secondly, several gastric carcinoma models were established through inoculation 2×106 BGC-823 gastric carcinoma cells subcutaneously. Thirdly, micro-CT scanning was performed after accumulative enhancement method of intraperitoneal injection of 360 mg omnipaque contrast agent containing iodine with a concentration of 350

mg/ml. Finally, we obtained high-resolution anatomical information of the metastasis in vivo in a BALB/c NuNu mouse, the 3D tumor architecture is revealed in exquisite detail at about 60 µm spatial resolution. In addition, the accurate shape and volume of the micrometastasis as small as 0.78 mm3 can be calculated with our software. Overall, our data suggest that this imaging approach and system could be used to enhance the understanding of tumor proliferation, metastasis and could be the basis for evaluating anti-tumor therapies.

7965-21, Session 4

Time-course characterization of an aqueous colloidal polydisperse contrast agent in mice using micro-computed tomography

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Background: Evaluation of cardiovascular function in mice using micro-CT requires that a contrast agent (CA) be administered to differentiate the blood from the myocardium. eXIA 160, an aqueous colloidal poly-disperse CA with a high concentration of iodine (160g I/mL), creates strong contrast between blood and tissue with a low injection volume. In this study, the blood-pool enhancement time-course of eXIA 160 is monitored over a 24-hour period to determine its optimal use during cardiac function studies.

Methods/Results: 8-second scans were performed (80kVp, 110mA) using the GE Locus Ultra micro-CT scanner. Male mice (black, 22-24g) were injected via tail vein with 5 µl/g body weight eXIA 160 (Binitio Biomedical Inc.). A precontrast scan was performed; following injection, mice were scanned at 15, 30, 45, and 60 minutes, 2, 4, 8, and 24 hours. Overall, the highest contrast in the left ventricle occurred at 15 minutes (700 HU). Uptake of the CA by the myocardium was also observed: myocardial tissue showed increasing enhancement over a 4-hour period, remaining even once the contrast was eliminated from the vasculature.

Conclusion: eXIA 160 provided high contrast between blood and myocardial tissue for a period of 30 minutes following injection. Notably, this CA was also taken up by the myocardium and provided continued contrast when the contrast agent was eliminated from the blood, making LV wall function studies possible. In conclusion, eXIA 160, with its high iodine concentration and targeted tissue uptake characteristics, make it an ideal agent to use when evaluating cardiovascular function in mice.

7965-22, Session 4

Implementation and assessment of an animal management system for small-animal micro-CT / micro-SPECT imaging

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Advances in laboratory imaging systems for CT, SPECT, MRI, and PET facilitate routine micro-imaging during pre-clinical investigations. Challenges still arise when dealing with immune-compromised animals, biohazardous agents, and multi-modality imaging. These challenges can be overcome with an appropriate animal management system (AMS), with the capability for supporting and monitoring a rat or mouse during micro-imaging. We report the implementation and assessment of a new AMS system for mice (PRA-3000 / AHS-2750, ASI Instruments, Warren MI), designed to be compatible with a commercial micro-CT / micro-SPECT imaging system (eXplore speCZT, GE Healthcare, London ON). The AMS was assessed under the following criteria: 1) compatibility with the imaging system (i.e. artifact generation, geometric dimensions); 2) compatibility with live animals (i.e. positioning, temperature regulation, anesthetic supply); 3) monitoring capabilities (i.e. rectal temperature, respiratory and cardiac monitoring); 4) stability of co-registration; and 5) containment. Micro-CT scans performed using a standardized live-animal protocol (90 kVp, 40 mA, 900 views, 16 ms per view) exhibited low noise (±19 HU) and minimal artifact from high-density components within the AMS (e.g. ECG pad contacts). Live mice (C57BL/6) were imaged repeated (with removal and replacement of the AMS) and spatial registration was found to be stable to within ±0.1 mm. All animals tolerated enclosure within the AMS for extended periods (> one hour) without distress, based on continuous recordings of rectal temperature, ECG waveform and respiratory rate. A sealed AMS system extends the capability of a conventional micro-imaging system to include immune-compromised and biosafety level 2 mouse-imaging protocols.

7965-23, Session 5

Effect of registration on corpus callosum population differences found with DBM analysis

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Deformation Based Morphometry (DBM) is a relatively new method used for characterizing anatomical differences among populations. DBM is based on the analysis of the deformation fields generated by non-rigid registration algorithms, which warp the individual volumes to one standard coordinate system. Although several studies have compared non-rigid registration algorithms for segmentation tasks, few studies have compared the effect of the registration algorithm on population differences that may be uncovered through DBM. In this study, we compared DBM results obtained with five well established non-rigid registration algorithms on the corpus callosum (CC) in thirteen subjects with Williams Syndrome (WS) and thirteen Normal Control (NC) subjects. The five non-rigid registration algorithms include: (1) The Adaptive Basis Algorithm (ABA); (2) Image Registration Toolkit (IRTK); (3) Automatic Registration Tools (ART); (4) FSL Nonlinear Image Registration Tool (FNIRT); and (5) the normalization algorithm available in SPM. For each algorithm, the 3D deformation fields from all subjects to the atlas were obtained and used to calculate the Jacobian determinant (JAC) at each voxel in the mid-slice of the CC. The mean JAC maps for each group were compared quantitatively across different nonrigid registration algorithms. An ANOVA test performed on the means of the JAC over Genu and Splenium ROIs shows that JAC differences between nonrigid registration algorithms are statistically significant for the Genu for both groups and for the Splenium for the NC group. These results suggest that it is important to consider the effect of registration when using DBM to compute morphological differences in populations.

7965-24, Session 5

Automated segmentation of ventricles from serial brain MRI for the quantification of volumetric changes associated with communicating hydrocephalus in patients with brain tumor

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Accurate ventricle volume estimates could improve the understanding and diagnosis of postoperative communicating hydrocephalus. For this category of patients, associated changes in ventricle volume can be difficult to identify, particularly over short time intervals. We present an automated segmentation algorithm that evaluates ventricle size from serial brain MRI examination. The technique combines serial T1-weighted images to increase SNR and segments the means image to generate a ventricle template. After pre-processing, the segmentation is initiated by a fuzzy c-means clustering algorithm to find the seeds used in a combination of fast marching methods and geodesic active contours. Finally, the ventricle template is propagated onto the serial data via

non-linear registration. Serial volume estimates were obtained in an automated robust and accurate manner from difficult data.

7965-25, Session 5

Assessment of variability in cerebral vasculature for neuro-anatomical surgery planning in rodent brain

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Clinical and pre-clinical studies show that deep brain stimulation (DBS) of targeted brain regions by neurosurgical techniques ameliorate psychiatric disorder such as anorexia nervosa. Neurosurgical interventions in preclinical rodent brain are mostly accomplished manually with a 2D anatomical atlas, with no vasculature information. Considering both the large number of animals subjected to stereotactic surgical experiments and the imaging cost, feasibility of sophisticated pre-operative imaging based surgical path planning and/or robotic guidance is limited. Here, we spatially normalize vasculature information to an anatomical atlas and asses the intra-strain variability in cerebral vasculature for planning neurosurgery experiments. By co-registering and subsequently building a probabilistic vasculature template in a standard space, we evaluate the risk of damaging blood vessels by a user defined electrode trajectory. The use of such a method may not only be confined to DBS therapy in small animals, but also could be readily applicable to a wide range of stereotactic small animal surgeries like targeted injection of contrast agents and cell labeling applications, where deleterious effects on blood vessels are to be minimized.

7965-26, Session 5

Using tensor-based morphometry to detect structural brain abnormalities in rats with intermittent alcohol exposure

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Understanding the effects of adolescent binge drinking that persist into adulthood is a crucial public health issue. Adolescent intermittent ethanol exposure (AIE) is an animal model that can be used to investigate these effects in rodents. In this work, we investigate the application of a particular image analysis technique, tensor-based morphometry, for detecting anatomical differences between AIE and control rats using Diffusion Tensor Imaging (DTI). Deformation field analysis is a popular method for detecting volumetric changes analyzing Jacobian determinants calculated on deformation fields. Recent studies showed that computing deformation field metrics on the full deformation tensor, often referred to as tensor-based morphometry (TBM), increases the sensitivity to anatomical differences. In this paper we conduct a comprehensive TBM study for precisely locating differences between control and AIE rats. Using a DTI RARE sequence designed for minimal geometric distortion, 12-directional images were acquired post-mortem for control and AIE rats (n=9). After preprocessing, average images for the two groups were constructed using an unbiased atlas building approach. We non-rigidly register the two atlases using Large Deformation Diffeomorphic Metric Mapping, and analyze the resulting deformation field using TBM. In particular, we evaluate the tensor determinant, geodesic anisotropy, and deformation direction vector (DDV) on the deformation field to detect structural differences. This yields data on the local amount of growth, shrinkage and the directionality of deformation between the groups. We show that TBM can thus be used to measure group morphological differences between rat populations, demonstrating the potential of the proposed framework.

7965-27, Session 5

Functional connectivity comparison of the default mode network in non-depressed Parkinson disease and depressed Parkinson disease

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Examining the intrinsic brain activity to understand the neural mechanism of brain disorders and establish neuroimaging-based disease-related biomarkers is a focus in recent resting-state functional MRI (fMRI) studies. The present study hypothesized that resting activity in the default mode network (DMN), which was used to characterize the resting-state human brain might be different in patients with depressed Parkinson disease (dPD) compared with non-depressed Parkinson disease (ndPD) patients. To test the hypothesis, we firstly employed the Group independent component analysis (Group ICA) approach to isolate the DMN for the two groups by analyzing the resting-state fMRI data from a group of 12 patients with dPD and a group of 12 age-matched ndPD subjects. And then the between-group comparison of the functional connectivity in the DMN was performed to examine the impact of depression on the intrinsic activity in PD. We found the core region from the network the medial prefrontal cortex (MPFC) show significant decreased activity in dPD group compared with ndPD group. In addition, the left inferior parietal cortex (lIPC) and the left inferolateral temporal cortex (lITC) also show decreased activity in dPD. This study suggests that depression in PD might be associated with dysfunction in the area of the frontal lobe from the DMN, in which the resting activity may serve as potential biomarkers for the development of depression in PD.

7965-28, Session 6

Novel hardware developments in magnetic particle imaging

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In 2005, Magnetic Particle Imaging (MPI) has been introduced as a new modality that allows for the acquisition of three-dimensional functional images with high sensitivity in real time. In this contribution, alternative coil topologies are presented that differ significantly from the original set-up.

Super-paramagnetic iron oxide nanoparticles (SPIONs) are used as tracer in MPI. The SPIONs are directly imaged due to their inherent non-linear magnetization properties measured in spatiotemporally changing magnetic fields. While driving a gradient field through the space, only those particles contribute to the measured signal whose variation in magnetization are not suppressed by saturation. These very particles are located within or in the vicinity of an offset-free area, the zero-level of the gradient field.

Two novel coil topologies will be presented. Beside an asymmetric coil topology, where all field generating coils are arranged on a single side, an effective coil assembly has been accomplished that creates a field-free line for spatial coding. In experimental validations it could be confirmed that the asymmetric coil topology achieves the image quality that has been forecasted in simulations of the entire imaging chain.

It could be demonstrated that the new coil set-ups assemble advantages compared to the symmetric cylinder geometry. Particularly for the novel concept of the field-free line, it can be expected a significant increase in sensitivity at a moderate rise of electric power loss. In conclusion, alternative coil topologies can overcome the problem of a confined measurement field or lead to an increase of the sensitivity of MPI.

7965-29, Session 6

Experimental demonstration of x-space magnetic particle imaging

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Recent image reconstruction work in Magnetic Particle Imaging gives the received signal as a function of position, and model based reconstruction through system modeling. These works discuss MPI in frequency space and require inversion of a matrix system that grows linearly with the number of voxels. If the matrix is ill-conditioned, it is well known that inversion leads to noise gain in the final image reconstruction.

We have developed a new image reconstruction technique, x-Space MPI, which does not require image reconstruction beyond simple scaling and mapping of the raw signal to image space. Reconstruction time scales linearly with image size. Moreover, we expect there to be no noise gain due to an ill-conditioned matrix inverse.

So far, there has not been an experimental test of the x-Space theory on an imaging system. In this paper we describe the construction of a small scale MPI imager to test x-Space theory. We describe the theoretical signal that we would expect from the imager for a SPIO nanoparticle source. We conclude with an image from the x-Space scanner with Resovist tracer. Our preliminary images show 1.9 mm spatial resolution using a 6.5 T/m gradient that closely matches the expected image resolution from theory.

In conclusion, our data supports the theory that MPI can be considered a linear, shift invariant system. This bodes well for future scale MPI scanners as large images can be reconstructed simply and rapidly.

7965-30, Session 6

Three-dimensional scanner for magnetic particle imaging

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Magnetic particle imaging (MPI) is a promising new imaging method capable of determining the spatial distribution of magnetic nanoparticle tracers in real-time. By means of a time-varying magnetic field the non-linear response of the particles is observed. Under constraints of an additional gradient field an image is reconstructed from the resulting spectrum of higher harmonics.

In this work, a three-dimensional magnetic particle imaging scanner is described. The system performs high-speed image acquisition with an estimated field of view of 25x25x15 mm. The object under investigation is placed in a tube of 30 mm diameter, fitting a ventilated mouse under laboratory conditions. The selection field gradient of 3 to 6 T/m is created by a combination of a NdFeB permanent magnet and a pair of Maxwell coils. For drive field generation three pairs of coils in Helmholtz-type configuration are used. The orthogonal drive fields are operated by an audio power amplifier tuned to frequencies around 10 kHz with maximum amplitude of 50 mT. The coil system is water-cooled for stable long-term operation. The read-out signal from the induction coil sensors passes an ultra low noise amplification stage gaining signal-to-noise in order to resolve small amounts of nanoparticles in the imaging plane.

In progress on the way to three-dimensional imaging, initial two-dimensional imaging results of a phantom obtained with the setup are presented. Suitability of the constructed scanning device for imaging concentrations of magnetic nanoparticles in a volume is demonstrated.

7965-31, Session 6

Biocompatible magnetite (Fe3O4) nanoparticles optimized for MPI spatial resolution

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Magnetic Particle Imaging (MPI), a new imaging modality suitable for human or animal subjects, is seemingly ideal for molecular imaging applications that utilize magnetic nanoparticle probes. However, MPI requires extremely high-quality magnetic particles to achieve theoretical imaging sensitivity and spatial resolution. Currently, after substantial recent progress in imager design and the theory of MPI imaging, it is at the core of MPI - the magnetic particles - where progress is lagging. To address this gap, we present experimental results that demonstrate the suitability for MPI of magnetite nanoparticles synthesized in our lab. We focus here on improving MPI spatial resolution with large (20-30 nm magnetic core diameter), monodisperse and biocompatible magnetite nanoparticles (MNPs).

MNPs were synthesized in organic solvents to ensure uniform and controllable size. To ensure suitability for biological imaging, MNPs were subsequently transferred into aqueous solution using biocompatible amphiphilic polymers. MNP magnetic properties were fully characterized by vibrating sample magnetometer and their effective magnetic core size, and distribution of core sizes, was determined. Experimental MPI results were acquired using a home-built MPI spectrometer that excites MNP magnetization and measures the spectral content of the emf induced in a receive coil. The spectrometer operates at 25 kHz and measures up to 40 harmonics in the MPI signal. Compared with commercially available particles (Feridex I.V.(TM) and Resovist(TM)) our MNPs show increased harmonic amplitude and more detectable harmonics. We use a model of dynamic MNP magnetization to interpret our results, which indicate that sub-millimeter spatial resolution is achievable with our particles.

7965-32, Session 6

Development of a field free line magnet for projection MPI

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The field free line (FFL) magnet has the potential to greatly increase signal to noise ratio (SNR) or decrease scan time for magnetic particle imaging (MPI). The use of an FFL will have a square root of N effect on the SNR for a constant scan time where N is the number of lines in the image. A FFL would enable projection imaging as is used in projection x-ray and is common in angiography. The Lubeck group has pioneered the design of field free line magnets for MPI. They have shown that they can achieve efficiency similar to that of a field free point, the standard in MPI.

Current FFL magnet designs have not been optimized in all characteristics such as gradient efficiency and gradient magnitude homogeneity along the FFL. This work shows that an eight segment Halbach quadrupole magnet design will produce a more homogeneous magnetic field along the field free line, which should result in a better quality image. In future work, we plan to use linear programming to create a more open design while optimizing magnet design characteristics using convex optimization theory.

7965-33, Session 6

MSB estimation chemical binding affinity

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Binding affinity can be estimated in several ways in the laboratory but there is no viable way to estimate binding affinity in vivo. Magnetic

spectroscopy of nanoparticle Brownian motion, MSB, measures the rotational Brownian motion. The MSB signal is affected by nanoparticle binding affinity so it provides a mechanism to measure the chemical binding affinity. We present a possible mechanism to quantify the binding affinity through the relaxation. The relaxation time reflects the rate of rotational Brownian motion. The MSB signal is a function of the product of the frequency and the relaxation time. The change in relaxation time when nanoparticles bind can be approximated. If the MSB signal for nanoparticles in two bound states is measured over several frequencies, the scale space correlation provides an estimate of the change in relaxation time. The relaxation time reflects the energy barrier to rotational motion, which for randomly oriented nanoparticles is the binding energy. The MSB signal is the same as that used by magnetic particle imaging which can be measured in vivo from very low concentrations of magnetic nanoparticles.

7965-34, Session 7

MPI cell tracking: What can we learn from MRI?

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MRI cell tracking using superparamagnetic iron oxide particles (SPIO) has found many applications in understanding cell biology and developing cell therapy. However, due to its indirect detection of cells through the SPIO effect on proton relaxation, there are several limitations that prevent its full exploitation. These include 1) the difficulty to absolutely quantify cell concentration and iron content - part of the difficulty relies in the existence of different relaxation regimes (dependent on the agglomeration state and size of SPIO cluster); 2) the difficulty of discriminating SPIO-labeled cells in areas of hemorrhage and traumatic injury (which are often present in targets of cell therapy), as caused by the proton dephasing effects of methemoglobin, ferritin, and hemosiderin (especially at higher fields); 3) the occasional misinterpretation of isolated “black spots” due to differences in magnetic susceptibility effects around blood vessels and air-tissue interfaces (i.e. stomach and GI tract); and 4) the inability to track cells in areas devoid of proton signal (i.e., the lungs).

Magnetic particle imaging (MPI) promises to take away some of these limitations. First described in 2005, it relies on the non-linear response of magnetic material as a direct manner for detecting the presence of an iron oxide nanoparticle agent in an oscillating magnetic field. Spatial encoding can be realized by a static, inhomogeneous magnetic field, saturating the magnetic material almost everywhere except in the vicinity of a special point, the field free point.

At the present time, it has been shown that stem cells can be readily detected with an MPI spectrometer at biologically relevant concentrations. Importantly, MPI enables a linear quantification of both cell number and iron content over a wide range of concentrations, regardless of the state of SPIO as free or intracellular entity. Whether or not in conjunction with MRI, MPI cell tracking appears promising and may become translational as there are no physical constraints against building human scanners, and certain SPIO formulations can be used that are already in use as clinical MRI cell tracking agents.

7965-35, Session 7

First phantom and in vivo images for an extended field of view from MPI

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Magnetic Particle Imaging (MPI) is a potential new medical imaging modality that has been introduced in 2005. MPI uses the non-linear magnetization behavior of iron-oxide based nano-particles, named a tracer, to perform quantitative measurements of their local concentration. Previous publications demonstrated the feasibility of real-time in vivo 3D imaging with clinical concentration of Resovist®. Given MPI’s fast, accurate and sensitive imaging as well as its overall versatility, it has potential to support various medical applications spanning from diagnostics to therapy. As an example, ongoing research investigates the use of MPI in cardiovascular diagnostics for myocardial perfusion measurement and for cancer therapy by hyperthermia.

While previous publications reported results from experimental systems with limited bore size (e.g. 3cm), this contribution presents first phantom and in vivo images acquired on the next hardware generation, an experimental system with an effective bore size of up to 12cm. The system is designed to support pre-clinical studies and can capture image data from an extended field of view, previously out of reach for smaller systems. The contribution introduces concepts for the encoding of a larger field of view by means of additional magnetic fields, named focus-fields, and provides details on multi-station reconstruction. To prove the feasibility of imaging an extended field of view, volumetric images of static and dynamic phantoms, as well as first dynamic sequences of the blood flow through the cardiovascular system of a rodent will be presented.

7965-36, Session 7

Multi-modality PET-CT imaging of breast cancer in an animal model using nanoparticle x-ray contrast agent and 18F-FDG

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Multi-modality PET-CT imaging enables functional and high-spatial resolution imaging of solid tumors. The use of different probes with these imaging modalities provides additional information about the ‘functional’ status of angiogenesis and cancer cells. In this study, we utilized (1) a nanoparticle X-ray contrast agent to image tumor vasculature and vessel ‘leakiness’ and, (2) 18F-FDG to investigate the functional status of tumor cells. Specifically, we sought to investigate whether tumor uptake of a nanoparticle X-ray contrast agent correlates with tumor uptake of 18F-FDG. In vivo studies were performed in mice implanted with 4T1 mammary breast cancer cells. Longitudinal micro-CT studies were performed to visualize vasculature and nanoparticle extravasation in the tumor. The same animals were imaged for 18F-FDG at multiple time points. At the end of imaging study, the tumors were extracted and immunohistology was performed to assess tumor viability and micro-vessel density. Early-phase micro-CT imaging enabled visualization of the tumors 3D vascular architecture in exquisite detail with 82.25-micron voxel size. Delayed-phase imaging enabled visualization of nanoparticle accumulation in the tumor. Both the imaging modalities demonstrated the presence of a necrotic core as indicated by hypo-enhanced signal in central region of the tumor. At delayed time-points, the tumor enhancement in 18F-FDG micro-PET images correlated well with those obtained with CT delayed enhancement. Lymph nodes were also enhanced in delayed-phase micro-CT images. The imaging approach described in the study could be used to better understand tumor angiogenesis and be the basis for monitoring and evaluating anti-angiogenic and nano-chemotherapies.

7965-37, Session 7

Preliminary clinical results: an analyzing tool for 2D optical imaging in detection of active inflammation in rheumatoid arthritis

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Optical imaging (OI) is a relatively new method in detecting active inflammation of hand joints of patients suffering from rheumatoid arthritis (RA). With the high number of people affected by this disease especially

in western countries, the availability of OI as an early diagnostic imaging method is clinically highly relevant. In this paper, we present a newly in-house developed OI analyzing tool and a clinical evaluation study. Our analyzing tool extends the capability of existing OI tools. We include many features in the tool, such as region-based image analysis, hyperperfusion curve analysis, and multi-modality image fusion to aid clinicians in localizing and determining the intensity of inflammation in joints. Additionally, image data management options, such as the full integration of PACS/RIS, are included. In our clinical study we demonstrate how OI facilitates the detection of active inflammation in rheumatoid arthritis. The preliminary clinical results indicate a sensitivity of 43.5% (35.3% - 52.1%), a specificity of 80.3% (74.8% - 84.8%), an accuracy of 65.7%. The accuracy of inflammation detection serves as evidence to the potential of OI as a useful imaging modality for early detection of active inflammation in patients with rheumatoid arthritis. With our in-house developed tool we extend the usefulness of OI imaging in the clinical arena. Overall, we show that OI is a fast, inexpensive, non-invasive and non-ionizing yet highly sensitive and accurate imaging modality.

7965-38, Session 7

An image analysis system for near-infrared (NIR) fluorescence lymph imaging

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Quantitative analysis of lymphatic function is crucial for understanding the lymphatic system and diagnosing the associated diseases. Recently, a near-infrared (NIR) fluorescence imaging system is developed for real-time imaging lymphatic propulsion by intradermal injection of microdose of a NIR fluorophore distal to the lymphatics of interest. However, the previous analysis software is underdeveloped, requiring extensive time and effort to analyze a NIR image sequence. In this paper, we develop a number of image processing techniques to automate the data analysis workflow, including an object tracking algorithm to stabilize the subject and remove the motion artifacts, an image representation named flow map to characterize lymph flow more reliably, and a fully automatic algorithm to compute lymph velocity and frequency of propulsion. By integrating all these techniques to a system, the analysis workflow significantly reduces the amount of required user interaction and improves the reliability of the measurement.

7965-59, Poster Session

Texture-based segmentation and analysis of emphysema depicted on CT images

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In this study we present a texture-based method of emphysema segmentation depicted on CT examination consisting of two steps. Step 1, a fractal dimension based texture feature extraction is used to initially detect base regions of emphysema. A threshold is applied to the texture result image to obtain initial base regions. Step 2, the base regions is evaluated pixel by pixel using a method that considers the variance change incurred by adding a pixel to the base region. The second step refines the boundary of the base regions to produce a reasonable segmentation of the emphysema regions based on visual inspection. There was a significant correlation between lung function (FEV1, FEV1/FVC, and DLCO) and fraction of emphysema computed using the texture based method, which were -0.433, -.629, and -0.527, respectively. The texture-based method produced more homogeneous emphysematous regions compared to simple thresholding, especially for large bulla, which can appear as more speckled regions in the threshold approach. The texture-based method also removed single isolated pixels in the lung parenchyma that do not appear to be associated to emphysema, which again are identified as emphysema by the threshold approaches. The strength of our complex texture-based approach to emphysema segmentation is that goes beyond existing studies that typically extract a single or groups texture features and individually analyze the features. We focus on first identifying potential regions of emphysema and then refining the boundary of the detected regions based on texture patterns.

7965-67, Poster Session

Three-dimensional automatic computer aided evaluation of pleural effusions using chest CT images

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The ability to estimate the volume of pleural effusions is desirable as it can provide information about the severity of the condition and the need for thoracentesis. We present here an improved version of an automated program to measure the volume of pleural effusions using regular chest CT images. First, the lungs are segmented using region growing, mathematical morphology, and anatomical knowledge. The visceral and parietal layers of the pleura are then extracted based on anatomical landmarks, curve fitting and active contour models. The liver and compressed tissues are segmented out using thresholding. The pleural space is then fitted to a Bezier surface which is subsequently projected onto the individual two-dimensional slices. Finally, the volume of the pleural effusion is quantified. Our method was tested on 15 chest CT studies and validated against three separate manual tracings. The Dice coefficients were 0.74±0.07, 0.74±0.08, and 0.75±0.07 respectively, comparable to the variation between two different manual tracings.

7965-68, Poster Session

Quantitative computed tomography of lung parenchyma in patients with emphysema: analysis of higher-density lung regions

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Quantitative computed tomography (CT) has been widely used to detect and evaluate the presence (or absence) of emphysema on density masks techniques applied at specific thresholds, e.g., -910 or -950 Hounsfield unit (HU). However, it has also been observed that subjects with similar density-mask based emphysema scores could have widely varying lung function, possibly indicating differences of disease severity. To assess this possible discrepancy, we investigated whether density distribution of “viable” lung parenchyma regions with pixel values > -910 HU correlate with lung function. A dataset of 38 subjects who underwent both pulmonary function testing and CT examinations in a COPD SCCOR study was assembled. After the lung regions depicted on CT images were automatically segmented by a computerized scheme, we systematically divided the lung parenchyma into different density groups (bins) and computed a number of statistical features (i.e., mean, standard deviation (STD), skewness of the pixel value distributions) in these density bins. We then analyzed the correlations between each feature and lung function. The correlation between diffusion lung capacity (DLCO) and STD of pixel values in the bin of was 0.43, as compared with a correlation of -0.49 obtained between the post-bronchodilator ratio between the forced expiratory volume in 1 second (FEV1) and forced vital capacity (FEV1/FVC) and the STD of pixel values in the bin of . The results showed an association between the distribution of pixel values in “viable” lung parenchyma and lung function, which indicates that similar to the conventional density mask method, the pixel value distribution features in “viable” lung parenchyma areas may also provide clinically useful information to improve assessments of lung disease severity as measured by lung functional tests.

7965-69, Poster Session

Ventilation-perfusion study without contrast media in dynamic chest radiography

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Pulmonary ventilation and blood flow are reflected in dynamic chest radiographs as changes in X-ray translucency, i.e., pixel values. This study was performed to investigate the feasibility of ventilation-perfusion (V/Q) study based on the changes in pixel value on breathing chest radiographs without contrast media. Sequential chest radiographs of a patient with V/Q mismatch were obtained during respiration using a dynamic flat-panel detector (FPD) system. Average pixel values were measured in each local area, tracking and deforming the region of interest. Inter-frame differences were then calculated, and the absolute values were summed in each respiratory phase. The percentage of summation in each area to total summation in the whole lung area was calculated and visualized as ventilation and blood flow distribution map, respectively. The result images were compared to distribution of radioactive counts on ventilation and perfusion scintigrams, respectively. Furthermore, V/Q ratio was calculated from the changes in pixel value in each local area and compared to V/Q ratio obtained from radioactivity counts. In the results, abnormalities were appeared as a reduction of changes in pixel values, and a correlation was observed between the distribution of changes in pixel value and those of radioactivity counts (Ventilation; r=0.78, Perfusion; r=0.77). V/Q mismatch was also indicated as mismatch of changes in pixel value, and a correlation with V/Q calculated by radioactivity counts (r=0.78). These results indicated that the present method is potentially useful for V/Q study as an additional examination in conventional chest radiography.

7965-70, Poster Session

Fully automated adipose tissue measurement on abdominal CT

J. Yao, D. L. Sussman, R. M. Summers, National Institutes of Health (United States)

Obesity has become widespread in America and has been associated as a risk factor for many illnesses. Adipose tissue (AT) content, especially visceral AT (VAT), is an important indicator for risks of many disorders, including heart disease and diabetes. Measuring adipose tissue (AT) with traditional means is often unreliable and inaccurate. CT provides a means to measure AT accurately and consistently. We present a fully automated method to segment and measure abdominal AT in CT. Our method integrates image preprocessing which attempts to correct for image artifacts and inhomogeneities. We use fuzzy c-means to cluster AT regions and active contour models to separate subcutaneous and visceral AT. We tested our method on 50 abdominal CT scans. Our method gave strong agreement with measurements from two manual users (Pearson correlations for SAT were 0.994 and 0.996 and those for VAT were 0.967 and 0.989 respectively).

7965-71, Poster Session

Cardiac motion tracking approach with multilevel B-splines and SinMod from tagged MRI

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Cardiac motion analysis can play an important role in cardiac disease diagnosis. Since its development in the late 1980's by Zerhouni and Axel, tagged MRI has been widely used and has proven to be an excellent quantitative technique for measuring myocardial deformations. Tags appear as an undeformed dark grid when imaged immediately after the application of tag pattern which deform with the heart as it contracts, allowing local indices of deformation to be estimated.

In this paper, we aim to develop a method that combines the advantages of continuity and smoothness of multilevel B-splines, and makes use of phase information derived from tagged MR images. In our previous work, we used virtual tag line intersections produced by HARP. In this paper, the virtual tag line intersections are obtained from SinMod technique. Different from HARP, SinMod detects both the local spatial phase shift and spatial frequency in band-pass filtered images, while HARP uses phase invariant condition and tracks local spatial phase. The speed of SinMod method is as fast as HARP but SinMod has advantages in accuracy, noise reduction, and avoidance of artifacts. By considering real tag intersections and virtual tag intersections as scattered data, multilevel B-splines can result in accurate and fast approximation without specifying the control point locations explicitly. Dense virtual tag intersections based on SinMod were created and incorporated into a multilevel B-spline fitting process.

Experimental results on simulated data from the 13-parameter kinematic model of Arts and in vivo canine data demonstrate further improvement in accuracy and effectiveness of the proposed method.

7965-72, Poster Session

Lung registration using airway tree morphometry

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This paper describes a non-linear medical image registration algorithm that aligns lung CT images scanned at different respiratory phases. The method uses landmarks obtained from the airway tree to find the airway branch extension lines and where the lines intersect the lung surface. The branch extension and lung intersection voxels on the surface were the crucial landmarks that initialize the non-rigid registration process. Registration accuracy was evaluated by the average distance between the corresponding airway tree branch end points in the two images. The mean value of the distance between landmarks in template images and deformed matching images across all subjects was 5.26mm (± 2.78mm). The lung image registration technique developed may prove useful in quantifying longitudinal changes, performing regional analysis, tracking lung tumors, and compensating for subject motion across CT images.

7965-73, Poster Session

Vascular landmark detection in 3D CT data

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This work presents novel methods to accurately placing landmarks inside the vessel lumen. This task is an important prerequisite to automatic centerline tracing. Methods have been proposed in the past to determine the location of organ landmarks, and yet several challenges remain for vascular landmarks. First, placing landmarks inside the lumen could be challenging for narrow vessels. Second, contrast-enhanced arteries could be tightly surrounded by bones with similar intensity profiles, making detection difficult compared to arteries surrounded only by darker tissues. Third, landmarks not located at bifurcations could be ill-defined as they have high uncertainty in position. We first present a method to detect landmarks that are located at vessel bifurcations. Such landmarks have well-defined positions, and we detect them using machine learning techniques. We then present a method to detect vascular landmarks not located at bifurcations. First, a segment detector is created to detect a vessel segment. Annotating multiple points along a vessel segment is easier than annotating a single landmark position, as there is no

well-defined position along a vessel. This resolves the ambiguity issue mentioned above. Second, spatial features are computed from the segment detector's response map, and a regression model is created which takes as input the local spatial features surrounding a voxel, and outputs a confidence score of how likely this voxel is inside the lumen. Using the proposed procedure, a landmark can be placed accurately inside the lumen in 1.5 seconds given a 100mm cubic subvolume. To evaluate the system a set of 94 datasets has been tested, achieving excellent results.

7965-74, Poster Session

Automated segmentation of intraretinal layers from spectral-domain macular OCT: reproducibility of layer thickness measurement

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Changes in intraretinal layer thickness occur in a variety of diseases such as glaucoma, macular edema, and type 1 diabetes. To segment the intraretinal layers from SD-OCT scans, we previously introduced an automated multiscale 3-D graph search method and validated its performance by computing unsigned border positioning differences when compared with human expert tracings. In addition to the unsigned border positioning error, the reproducibility of layer thickness is another good measurement for validation of the intraretinal layer segmentation method. Twenty eight (14 × 2) repeated macular OCT scans were acquired from the right eyes of 14 normal subjects using two Zeiss-Cirrus SD-OCT scanners. After segmentation of 10 intraretinal layers and registration of layer thickness maps from the repeated OCT scans, the reproducibility of layer thickness was estimated by calculating the differences of the layer thicknesses. The overall global mean thickness difference of the intraretinal layers is 2.43 ± 1.02 μm (1.22 ± 0.51 voxels). No specific local region showed consistent thickness difference across the layers, and the local mean thicknesses of all layers between the repeated OCT scans exhibited excellent correlations.

7965-75, Poster Session

A fast dynamic linked library based mixed-language programming technology for the trust region method in bioluminescence tomography

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Bioluminescence tomography (BLT) is a novel optical molecular imaging (MI) modality. It can reconstruct the inner bioluminescent light source distribution, according to the surface light distribution. The trust region method (TRM) can overcome the ill-posedness of BLT for its regularization property. As there exists a "TRUST" function that can solve the trust region subproblem in Matlab and Matlab's powerful matrix operation ability suited for TRM, the TRM is implemented in Matlab. Then the Matlab code of TRM is transformed into a dynamic linked library (DDL) and mixed together with the C++ code of the adaptive finite element (AFE) framework, using the mixed-language programming technology (MLPT). There are two main advantages of the MLPT. The first is taking advantages of all the participated programming languages. The second is time efficient. The usual way of transferring data between programmes written in different programming languages is to write the data first into files that are stored in the hard discs in one programme, and then read the files from another programme. Besides wasting time on writing and reading, it is difficult to keep the precision of the data. The DLL based MLPT can eliminate the need of installing code compilers in the platform running the software. Furthermore, in DLL, the code is implemented in C/C++ with high time efficiency, while the code in Matlab remains relatively low time efficiency. Finally, a numerical experiment is carried out to show MLPT's usage in the source reconstruction procedure of BLT, using the MLPT based on DLL.

7965-76, Poster Session

Bone texture analysis on dental radiographic images: results with several angulated radiographs on the same region of interest

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Bone microarchitecture is the predictor of bone quality or bone disease. It can only be measured on a bone biopsy, which is invasive and not available for all clinical situations. Texture analysis on radiographs is a common way to investigate bone microarchitecture. But relationship between 3-dimension histomorphometric parameters and 2-dimension texture parameters is not always well known, with poor results. The aim of this study is to perform angulated radiographs of the same region of interest and see if a better relationship between texture analysis on several radiographs and histomorphometric parameters can be developed. Computed radiography images of dog (Beagle) mandible section in molar regions were compared with high-resolution micro-CT (Computed-Tomograph) volumes. Four radiographs with 27° angle (up, down, left, right, using Rinn ring and customized arm positioning system) were performed from initial radiograph position. The five images were compared. The SWIFT software allows for finding the same points on the five images. Calculated simulations (suppression of cortical bone for example) were also obtained using Mojette Transform from micro-CT volumes. Bone texture parameters were calculated on all images. As related in a prior work, the Mojette transform was successful to obtain high quality images. Texture parameters calculated on simulations with and without cortical bone gave similar results. The texture parameters on angulated radiographs allowed a better correlation with bone microarchitecture. These results imply that measurement of texture parameters with some angulated radiographs could provide a good knowledge of bone quality and an easy diagnostic of bone disease.

7965-78, Poster Session

Evaluation of image quality characteristics of reduction image in high resolution liquid crystal display

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A recent mammogram is the small pixel size, and shows the tendency to grow by the matrix size. Therefore, it is thinned out, and the lack of the image information occurs when the entire image is displayed on a liquid crystal display (LCD). The display of the super-high resolution liquid crystal display (SHR-LCD) using a new resolution enhancement technology of the independent sub-pixel driving (ISD) that utilizes three sub-pixels in each pixel element was developed, because this problem is solved. However, the lack of the image information because of the thinning out display cannot be disregarded, because the matrix size of phase contrast mammogram (PCM) is very large compared with a past mammogram. To obtain a noise image and an edge image, we exposed by using geometrical layouts of the PCM(7080 9480).We obtained the noise and edge images, and measured the noise power spectrum (NPS) and the modulation transfer function (MTF) of the images reduced by nearest neighbor, bilinear, and bicubic (sharpness and smooth) interpolations. The reduction rate is approximately 0.14. We measured

NPS and MTF when the PCM image was displayed in 5 mega-pixel (MP) and 15MP. The result showed that the interpolation technique that gave the best image quality was bilinear. The image quality has been improved further by using 15MP SHR-LCD.

7965-79, Poster Session

White matter alterations in temporal lobe epilepsy

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Introduction: The temporal lobe epilepsy (TLE) is associated with hippocampal atrophy. However, the brain damage is not limited to limbic structures. The mechanisms underlying extrahippocampal brain damage in TLE are unknown. Seizures or medicines may lead to neuronal damage, but another possible explanation is deafferentation from loss of hippocampal connections. In this study we combined the use of Fractional anisotropy (FA), mean diffusibility (D), parallel diffusivity (D//) and perpendicular diffusivity (D), to localize the regions where occur axonal lesion and demyelization. Methods: Diffusion tensor imaging (DTI) was performed involving 33 patients with unilateral TLE (15 left and 18 right) and 20 healthy controls. Tract-based spatial statistics (TBSS) was applied to analyze the FA data. After, the regions with alteration were studied with D, D// and D maps. When compare with controls, the increase of D indicate demyelization and decrease of D can indicate axonal lesion. Results: Both patients with left- as well as right-sided mesial sclerosis exhibited widespread degradation of fractional anisotropy (FA). With D, D// and D maps analysis we found demyelization evidences in corpus callosum, corticospinal tract, fornix, internal capsule, corona radiate, Sagittal stratum, cingulum, fronto-occipital fasciculus and uncinate fasciculus. Evidences of Axonal lesion were found in internal capsule, thalamic radiation, sagittal stratum, cingulum and Uncinate fasciculus. Conclusions: DTI measures demonstrate widespread clusters of abnormal in prominent white matter tracts linking mesial temporal lobe structures with other brain areas. Our results are consistent with the hypothesis that exist demyelization and axonal damage in patients with temporal lobe epilepsy.

7965-80, Poster Session

fMRI analysis software tools: an evaluation framework

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Performance comparison of functional Magnetic Resonance Imaging (fMRI) software tools is a very difficult task. In this paper, a framework for comparison of fMRI analysis results obtained with different software packages is proposed. An objective evaluation is possible only after pre-processing steps that normalize input data in a standard domain. Segmentation and registration algorithms are implemented in order to classify voxels belonging to brain or not, and to find the non rigid transformation that best aligns the volume under inspection with a standard one. Through the definitions of intersection and union of the fuzzy logic we defined an index which quantify information overlap between Statistical Parametrical Maps (SPMs). Direct comparison between fMRI results can only highlights differences. Instead of assessing the best result an index that represents the goodness of the activation detection is required. The transformation of the activation map in a standard domain allows the use of a functional Atlas for labeling the active voxel. For each functional area we have defined the Activation Weighted Index (AWI) that identifies the mean activation level of whole area. By means of this synthetic but comprehensive description is easy to find a metric for the objective evaluation of a fMRI analysis tools. Trough the first evaluation method was identified the situations where the SPMs are inconsistent. The result of AWI analysis suggest which tool has higher sensitivity and specificity. The proposed method seems a valid evaluation tool when applied to an adequate number of patients.

7965-81, Poster Session

Prediction of fMRI time series of a single voxel using radial basis function neural network

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A great deal of current literature regarding functional neuroimaging has elucidated the relationships of neurons distributed all over the brain. Modern neuroimaging techniques, such as the functional MRI (fMRI), provide a convenient tool for people to study the correlation among different voxels as well as the spatio-temporal patterns of brain activity. In this study, we present a computational model using radial basis function neural network (RBF-NN) to predict the fMRI voxel activation with the activation of other voxels acquired at the same time. The fMRI data from a visual images stimuli presentation experiment was separated into two sets; one was used to train the model, and the other to validate the accuracy or generalizability of the model. In the visual stimuli presentation experiment, the subject did simple one-back-repetition tasks when four categories of stimuli (houses, faces, cars, and cats) were presented. Voxel sets A and B were selected by two different voxel selection criterion: (1) Voxel set A are those activated for any kind of object stronger than the other three objects in regions of interest (ROIs) without correction (P=0.001); (2) Voxel set B are those activated for at least one of the categories of stimuli within the ROIs (FWE correction, P=0.05). RBF-NN regression models construct the nonlinear relationship between the activation of voxels in A and B. Our test results showed that RBF-NN can capture the nonlinear relationship existing in neurons and reveal the relationship between voxel's activation from different brain regions.

7965-82, Poster Session

The impact of respiratory and cardiac effects on the phase and magnitude of resting-state fMRI data

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Functional magnetic resonance imaging (fMRI) relies on detecting small changes in signal during the brain activity, in which the influence of respiratory and cardiac physiological action is inevitable. There have been several methods proposed for removing physiologic noise, but to date there has been little work on the complex-valued fMRI data. We evaluated the impact of cardiac and respiratory activities on complex fMRI data acquired by scanning subjects during the resting-state on a Siemens 3T scanner. We utilized the RETROICOR algorithm on the complex fMRI data and produce spatial maps of the physiological fluctuation effects on human resting-state data, revealing the impact of respiratory and cardiac effects on the phase and magnitude of the resting-state image. Our results show than the impact of respiration and cardiac pulsation on resting-state brain fMRI is highly spatial variant (the brain region dependence of the effect maps), and that the effect map on magnitude image is different from that on phase image. We calculate the hemodynamic response functions (HRFs) using an iterative deconvolution algorithm. We characterize the HRFs for the subject for different scan sessions, voxels and durations. We also assess the intersubject variation of the HRF. With the assumption that a subject's respiratory and cardiac HRFs are invariant to scanning scenarios, we can use the precalculated HRFs (by convolving with the monitoring recordings of the respiratory and cardiac timeseries during an fMRI scanning) to predict the respiratory and cardiac effects on BOLD fMRI.

7965-83, Poster Session

A mean-sensitive spatial filtering (MSF) method for trial-by-trial analysis of N170 component

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N170 is an important neurophysiological index of face and object perception processes with specific spatio-temporal features. In this study, we focus on the mean of one event-related potential (ERP) component and propose a spatial filtering method that is sensitive to mean differences between stimuli conditions. MSF can extract spatial distribution patterns of N170 means and estimate a set of optimal vectors to strengthen features in single trials. Then, we apply these spatial filters to ERP data and perform classification on extracted features. In this way, the presence of a larger N170 by faces or a smaller N170 by objects can be detected robustly trial by trial and hereby we can infer the category of presented stimuli from faces and objects. Furthermore, we also successfully extracted less distinct spatial patterns between cars and cats with MSF and identified them correctly. These results suggest that MSF not only suits discriminating faces from objects but also works well to investigate spatial patterns and their similarities between objects. The remarkable and robust performances of our approach demonstrate that the spatial patterns of N170 mean values are stable enough to reveal visual information processing and thus single-trial N170 component along with MSF provides a promising solution for decoding mental states or a new-style human machine interactive application.

7965-84, Poster Session

Comparison of DSC - MRI perfusion quantification methods in the presence of delay and dispersion

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The perfusion of the brain is essential to maintain brain function. Stroke is an example of a decrease in blood flow and reduced perfusion. During ischemic stroke the blood flow to the tissue is hampered due to a clot inside the vessel. To investigate the recovery of stroke patients, follow up studies are necessary. MRI is the preferred imaging modality for follow up because of the absence of dose concerns, contrary to CT. Dynamic Susceptibility Contrast (DSC) MRI is nowadays increasingly used for measuring perfusion of the brain, however, is not standard applied in the clinical routine due to lack of patient benefit. Several post processing algorithms are described in the literature to obtain cerebral blood flow (CBF) and volume (CBV) values. The quantification of CBF relies on the deconvolution of a tracer concentration-time curve in an arterial and a tissue voxel. There are several methods to obtain this deconvolution. This contribution describes a comparison between the different approaches as currently there is no best practice for (all) clinical relevant situations. We evaluate computer simulation results together with a limited clinical data set. Comparisons with ground truth data are investigated at the moment; the MRI follow up scanning protocol is pending approval. Our aim is the best algorithm for the evaluation of perfusion in the presence of delay and dispersion in patient data and that is sensitive to detect the small changes in the patient's perfusion in the recovery process after ischemic stroke as revealed in follow up MRI scans.

7965-85, Poster Session

Cine phase-contrast MRI measurement of CSF flow in the cervical spine: a pilot study in patients with spinal cord injury

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MRI velocimetry (also known as Phase-Contrast MRI) is a powerful tool for quantification of cerebrospinal fluid (CSF) flow as it flows from the cerebral ventricles inside the brain, down to the skull base via the cerebral aqueduct, and to the spinal canal via the fourth ventricle and foramen magnum. Cerebrospinal fluid is continually produced in the brain, and is continually reabsorbed at a number of locations along the surface of the brain. Many diseases can change the shape of CSF flow waveform; these changes are visible via the CSF flow waveform obtained through phase-contrast MRI. CSF flow is pulsatile - flowing back and forth in the spinal canal. The direction and velocity of flow is determined by pulsation of the heart.

Although in the past, CSF flow has been studied through MRI in both the normal population as well as the diseased population, to date, no study has examined the pattern of CSF flow in patients suffering from spinal cord injury (SCI). In this pilot study, we examined CSF flow in 4 normal subjects and 2 subjects with non-acute injuries in the cervical spine using Cine- PC MRI. Cine flow was measured at 3 sites in the normal subjects: at the level of C2, at 5 cm distal to C2, and at 10 cm distal to C2. In subjects with spinal cord injury cine flow was measured at the site of injury, and at +/- 5 cm from the site of injury in the cervical spine.

Results: For the normal subjects, the average bulk CSF flow rate at site 1 was found to be 0.28 cc/min, at site 2 it was 0.1925 cc/min, and at site 3 it was 0.1675 cc/min consistent with previously published data. However, in subjects with spinal cord injury, the CSF flow pattern was random, and unpredictable. In the two subjects with SCI, the average bulk flow rate at the site of injury was 0.075 cc/min (subject 1: 0.16 cc/min, subject 2: - 0.01 cc/min), at -5 cm: 0.18 cc/min (subject 1: 0.13 cc/min, subject 2: 0.23 cc/min), and at +5cm distal to the injury: 0.12 cc/min (subject 1: 0.11 cc/min, subject 2: 0.13 cc/min).

7965-86, Poster Session

Comparison of gray matter volume and thickness for analysis of cortical changes in Alzheimer's Disease

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Gray matter volume and cortical thickness are two indices of concern in brain structure magnetic resonance imaging research. Gray matter volume reflects mixed-measurement information of cerebral cortex, while cortical thickness reflects only the information of distance between inner surface and outer surface of cerebral cortex. Using Scaled Subprofile Modeling based on Principal Component Analysis (SSM_PCA) and Pearson's Correlation Analysis, this study further provided quantitative comparisons and depicted both global relevance and local relevance to comprehensively investigate morphometrical abnormalities in cerebral cortex in Alzheimer's Disease (AD). Thirteen patients with AD and thirteen age- and gender-matched healthy controls were included in this study. Results showed that factor scores from the first 8 principal components accounted for ~53.38% of the total variance for gray matter volume, and ~50.18% for cortical thickness. Factor scores from the fifth principal component showed significant correlation. In addition, gray matter voxel-based volume was closely related to cortical thickness alterations in most cortical cortex, especially, in some typical abnormal brain regions such as insula and the parahippocampal gyrus in AD. These findings suggest that these two measurements are effective indices for understanding the neuropathology in AD. Studies using both gray matter volume and

cortical thickness can separate the causes of the discrepancy, provide complementary information and carry out a comprehensive description of the morphological changes of brain structure.

7965-87, Poster Session

Altered cortical anatomical networks in temporal lobe epilepsy

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Temporal lobe epilepsy (TLE) is one of the most common epilepsy syndromes with focal seizures generated in the left or right temporal lobes. With the magnetic resonance imaging (MRI), many evidences have demonstrated that the abnormalities in hippocampal volume and the distributed atrophies in cortical cortex. However, few studies have investigated if TLE patients have the alternation in the structural networks. In the present study, we used the cortical thickness to establish the morphological connectivity networks, and investigated the network properties using the graph theoretical methods. We found that all the morphological networks exhibited the small-world efficiency in TLE and normal groups. And the betweenness centrality analysis revealed that there were statistical inter-group differences in the right uncus region. Since the right uncus located at the right temporal lobe, these preliminary evidences may suggest that there are topological alternations of the cortical anatomical networks in TLE, especially for the right TLE.

7965-88, Poster Session

Abnormalities of hippocampal-cortical connectivity in the unilateral temporal lobe epilepsy (TLE) patients with hippocampal sclerosis

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Hippocampal sclerosis (HS) is the histological abnormality that most frequently associated with temporal lobe epilepsy (TLE). Many magnetic resonance imaging (MRI) studies have demonstrated the hippocampal atrophy in TLE-HS patients relative to normal controls. Thus, we hypothesized that the hippocampal-cortical interactions would change in TLE-HS patients as well. Some previous studies investigated connectivity with correlation analysis. In the present study, the left and right hippocampal volume was first measured in each subject, and we found that the ipsilateral hippocampal volume significantly decreased in the left TLE-HS patients. Then, the cortical thickness was calculated at each vertex throughout the whole brain. The correlation between unilateral hippocampal volume and cortical thickness at each vertex was employed to investigate the left or right hippocampal-cortical connectivity. Our study aimed to detect changes of ipsilateral hippocampal-cortical connectivity between unilateral TLE-HS patients and normal controls. For the left TLE-HS patients, we found significantly increased left hippocampal-cortical connectivity in the bilateral superior temporal gyrus, right cingulate gyrus and left parahippocampal gyrus. These significant abnormalities indicated structural vulnerability related to hippocampal sclerosis in the left TLE-HS patients.

7965-89, Poster Session

Transmit filter design methods for magnetic particle imaging

B. Zheng, P. Goodwill, S. Conolly, Univ. of California, Berkeley (United States)

Magnetic particle imaging (MPI) has emerged as a new imaging modality using the nonlinear magnetization behavior of superparamagnetic particles. Due to the need to avoid contamination from the transmit signal spectrum in the detected signal, MPI signal conditioning systems require different design considerations from MRI, where excitation and detection are temporally decoupled. In this paper, we describe two methods of filtering out higher order harmonic distortion in the transmit spectrum, which can arise from power amplifier nonlinearities. The first method uses a third-order balanced Butterworth topology as a lowpass filter. The second method uses an unbalanced third-order tuned elliptic filter cascaded with a third-order Butterworth filter. We show that whereas the Butterworth filter alone achieves around 20 and 30dB attenuation at the second and third harmonics, the cascaded filter can achieve around 60dB suppression of both harmonics before reaching the system noise floor.

7965-90, Poster Session

The impact of filtering direct-feedthrough on the x-space theory of magnetic particle imaging

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Magnetic particle imaging (MPI) is a new medical imaging modality that images the instantaneous response of super-paramagnetic particles under an applied magnetic field. When a sinusoidal excitation field is applied to the system, the received signal spectrum contains both harmonics from the particles and a direct feedthrough signal from the source at the fundamental drive frequency. Removal of the induced feedthrough signal from the received signal requires significant filtering, which may also remove part of the signal spectrum. In this paper, we decompose the received signal into harmonics and investigate the x-space impact of temporally filtering out individual harmonic. This builds on earlier work that discusses the ideal one-dimensional MPI system and harmonic decomposition of the MPI signal.

7965-91, Poster Session

Sensitivity improvement of the molecular imaging technique based on magnetic nanoparticles

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Magnetic particle imaging (MPI) using the nonlinear interaction between the internally administered magnetic nanoparticles (MNPs) and the electromagnetic waves irradiated from the outside of the body has attracted attention for the early diagnosis of diseases such as cancer. In MPI, the local magnetic field distribution is scanned, and the magnetization signal is detected from the magnetic nanoparticles inside an object region. However, interference of the magnetization signal generated from the MNPs outside a target region due to the nonlinear responses results in degradation of signal sensitivity. Although we proposed the image reconstruction method of suppressing an interference component while emphasizing a signal component using the property of the higher harmonic components generated from the MNPs, the edge part of the reconstructed image was emphasized excessively due to the high-pass-filter characteristics of this method. Here, we

proposed a new method based on the correlation information between the observed signal and a system function, and performed numerical analysis. As results, although image blurring was a little large, we clearly showed that an improvement of detection sensitivity can be improved without the inverse-matrix operation used by the conventional image reconstruction method.

7965-92, Poster Session

X-space MPI relaxometry: methods and initial data

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Magnetic Particle Imaging (MPI) is a new imaging modality promising high sensitivity, high-resolution imaging. Resolution and sensitivity are dependent on the size and relaxation characteristics of the superparamentic iron oxides (SPIO) nanoparticles used in the system. According to theory, the spatial resolution of MPI improves with the cube of the SPIO iron core diameter.

A system that can accurately and quickly measure the SPIO point spread function and relaxation constant would enable MPI researchers to decouple magnetic particle development and imaging system development. This system would enable magnetic nanoparticle manufacturers and MPI researchers to measure the intrinsic spatial resolution of the SPIOs to be used in the imaging system without an imager.

Here, we have developed a magnetic nanoparticle relaxometer that uses x-Space theory of MPI and a non-negative least squares with an optimal Tikhonov regularization fitting scheme to measure magnetic nanoparticle diameter, relaxation constant, and spatial resolution. Our measurements have excellent sensitivity and change little with independent, repeated measurements. While more experiments are necessary, our data lends the first experimental evidence to support the cubic dependence of spatial resolution on the magnetic nanoparticle diameter.

7965-93, Poster Session

The x-space formulation of magnetic particle imaging including non-negligible relaxation effects

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Magnetic particle imaging (MPI) is an emerging medical imaging modality that is predicted to have improved sensitivity and contrast as compared to existing technologies. MPI uses a strong magnetic field gradient (6.5 T/m) to spatially localize the induction response of superparamagnetic iron oxide nanoparticles (SPIOs), which are currently approved as a contrast agent for MRI. This new imaging modality has excellent contrast, spatial resolution, and will be safe for human use.

MPI relies on SPIO dipole moments aligning quickly with the applied magnetic field, but Neel and Brownian relaxation mechanisms can significantly retard this alignment. By causing this lag in magnetization alignment, relaxation ultimately degrades the resolution and accuracy of the MPI method. Our early simulation results indicate that relaxation effects in larger SPIOs could degrade spatial resolution by a factor of two or more. Our goal here is to develop a rigorous and predictive mathematical model for the imaging process including relaxation effects.

The X-space formulation of MPI previously developed by our group details the theoretical signal, bandwidth, resolution, SNR, and SAR of MPI; however this theory was formulated assuming negligible relaxation times. Here we updated the X-space analysis of MPI to include relaxation effects, and we have demonstrated excellent agreement with experimental MPI data. We believe an improved understanding of relaxation will be critical for SPIO design and MPI system optimization.

7965-94, Poster Session

Measuring soft tissue elasticity by monitoring surface acoustic waves using image plane digital holography

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The detection of tumors in soft tissues, such as breast cancer, is important to achieve at the earliest stages of the disease to improve patient outcome. However, the use of expensive, invasive, or radioactive medical imaging modalities is not recommended for routine screening applications. In fact, tumors often exhibit a greater elastic modulus compared to normal tissues. This property has been the source of great interest in the development of novel elastography techniques, i.e., techniques that image tissue elastic properties. We propose a novel method for non-invasively mapping elastic properties in soft tissues based upon holographic imaging of surface acoustic waves (SAWs). Holography provides nanoscale displacement resolution, while the recent availability of fast camera arrays provides high temporal resolution (<20μs in our study), obviating the need for expensive pulsed lasers when studying acoustic waves of typically 10-1000Hz. The relationship between SAW velocity and the depth-dependent elasticity of the medium provides a means of mapping the elastic properties inside tissues.

In this first study we demonstrate that the SAW velocity in response to a mechanical impulse is proportional to the square root of elastic modulus over a range from 0~122kPa, in homogeneous tissue phantoms composed of varying ratios of silicone oil and cross-linked polydimethylsiloxane. We furthermore show that the SAW velocity is not sensitive to the thickness of the sample over a range from 1-5cm. We are now characterizing the SAW distribution in multi-layer phantoms with varying elasticity using frequency-swept excitation to probe varying depths.

7965-95, Poster Session

Imaging Ca2+ mechanotrandsuction through a novel engineered polymer microenvironments for probing using dorsal cell adhesion

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The cell's chemical and mechanical milieu provides a range of stimuli that must be effectively integrated into intracellular signaling events for the regulation of cell function and physiology. Ca2+ is a ubiquitous messenger responsible for governing cell processes ranging from muscle contraction to gene transcription. To image Ca2+ response to both purinergic (P2Y) stimulus and mechanical perturbation through mature, dorsal focal adhesions, we cultured NIH 3T3 cells overnight within our quasi-3D (Q3D) culture environment, consisting of ordered polypropylene microfibers constructed over coverglass and mounted into an open-bath perfusion chamber. The Q3D system represents a new technology capable of inducing more physiological cell morphology, similar to 3D culture environment, but confining the cell to a single focal plane for imaging. The scaffold encompasses a 3-6 micron gap size, previously shown to allow dorsal cell attachment. We found cells formed more physiological, stellate/dentritic morphologies when attached between the glass and fiber compared with the typical laminar morphology observed with fibroblasts cultured on glass. Our results indicate that cells can frequently produce robust Ca2+ spikes in response to G-protein coupled receptor (GPCR) initiated stimuli, reset their spatiotemporal Ca2+ signal, and subsequently respond to mechanical stimulation (n = 7 cells), providing evidence that the Q3D system allows for the rapid manipulation of chemical milieu as well as the mechanical environment through

stretching of mature focal adhesions of stellate fibroblasts cultured in vitro. Compared with traditional techniques for mechanical probing (such as manipulation of microbeads affixed to the cellular surface), cells responded to Q3D manipulation with functionally unique calcium responses. Our studies indicate that geometrical environmental cues can play an important role in regulating calcium mechanotransduction.

7965-39, Session 8

A new methodology for detecting source number in MEG magnetic source imaging

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Advanced signal processing and modeling techniques such as Inverse problem, Subspace approach, and Independent component analysis (ICA), and Beamforming (BF) are used for magnetic sources imaging. The first three techniques require the source number be detected a priori, hence, data analysts have to run several models with various orders and then select numbers based on physiological plausibility. BF scans the source space on the point-to-point basis, hence, it counts the ``peaks" in the reconstructed magnetic source images (MSI) as the source number.

The physiological plausibility based and the ``peaks" selection based methods are somewhat subjective. Moreover, i) various MSIs employ different indexes, hence, they may not provide consistent number of ``peaks". ii) the highly correlated sources may reduce ``peaks" in MSI reconstructed by BF, hence, the numbers of ``peaks" counted in MSI are prone to be underestimated.

Our previous study "Source Counting in MEG Neuroimaging" (by Lei, et.al) proposed a model-fitting approach. It utilizes information theoretic criteria to detect the source number and is applied to the single trial of the experiment. This paper proposes a new approach, which is based on the multivariate analysis (Single value decomposition and Principal Component Analysis), utilizes discrimination of score vectors to select the source number, and is applied to the multiple trials of experiment.

The detection procedure of this approach is done before MSIs are generated, hence, the inconsistency caused by various MSIs and the underestimating tendency are avoided. It is a data-driven approaches, hence, it is not subjective. The good agreement between results from this approach and experts' evaluations demonstrate the promising.

7965-40, Session 8

A retrospective study of white matter integrity in mild cognitive impairment

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Prior work has shown that white matter fiber integrity decreases in Alzheimer's disease (AD) and mild cognitive impairment (MCI). This integrity can be quantified using diffusion tensor imaging techniques, which describe the anisotropic water movement in the brain. Since less than half of the MCI patients convert to AD, it is important to identify features that can predict the chance of conversion to AD within a certain time frame. In this study we apply tract-based spatial statistics (TBSS) in order to perform this task, overcoming limitations that are commonly associated with ROI-based approaches and voxel-based morphometry. Diffusion weighted images were taken from 15 healthy controls, 15 AD patients and 17 MCI patients. 8 MCI patients remained stable after 3 year follow-up investigations ("non-converters" or MCI-nc) and 9 converted to AD ("converters" or MCI-c). Significant differences between the MCI-nc and MCI-c groups were found in large parts of the fornix, the corpus callosum and the cingulum. In comparison, the MCI-c group did not differ significantly from the AD group and the MCI-nc group exhibited similar measures as the control group in most parts of the structures. These results demonstrate that, although MCI-c and MCI-nc patients were clinically similar at time of inclusion, the MCI-c group already exhibited pathologic features of fiber integrity associated with AD. This finding could lead to more powerful techniques in the early identification of AD and thus support an earlier and more successful treatment.

7965-41, Session 8

Rebuilding the injured brain: use of MRS in clinical regenerative medicine

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New powerful imaging tools allow researchers to track stem cells in vivo post transplant. However, neuroimaging still leaves numerous questions unresolved: How can we identify stem cells without using tracking agents, what cells types are destroyed in the brain post injury? What is the final phenotypic fate of transplanted cells? Are the transplanted cells still viable? Do the transplanted cells spare endogenous neuronal tissue? We hypothesize that magnetic resonance spectroscopy (MRS), a broadly used clinical technique that can be performed at the time of a standard MRI scan, can provide answers to these questions when coupled with advanced computational approaches. MRS is widely available clinically, and is a relative measure of different metabolites within the sampled area. These measures are presented as a series of peaks at a particular bandwidth that corresponds to an individual metabolite, such as lactate or creatine. The data are only subjectively interpreted by a neuroradiologist, but hold great potential if they were analyzed in a more objective manner. The overall purpose of the research described here is to develop pattern recognition algorithms for MRS data as a means to detect novel biomarkers or fingerprints of stem cells. Once identified, this technique will be used to identify in vivo transplanted stem cells within the brain.

7965-42, Session 8

Sparse brain network using penalized linear regression

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The majority of connectivity analyses in brain imaging has been on thresholding correlation in detecting focal regions. The main limitation based on correlation is that they fail to explicitly factor out the confounding effect of other regions. To remedy this limitation, partial correlation has been naturally introduced. Unfortunately, this type of problem usually belongs to the small-n large-p setting so it is not feasible to estimate the exact partial correlation. So far the majority of literature have used the penalized likelihood method in imposing the sparseness on the partial correlation estimation. In this study, we introduce a different approach based on the penalized linear regression for estimating sparse partial correlation. The penalized linear regression with l1-norm is known as least absolute shrinkage and selection operator (LASSO).

The proposed model is applied to the 97 regions of interest extracted from FDG-PET data for 26 autistic children and 11 pediatric control subjects. It is generally known that ASD has the global patterns of underconnectivity and the local patterns of overconnectivity in the key brain regions. The differences between autism and control are mostly found in connectivities between lobes, especially, connection between secondary association cortices such as frontal and parietal regions. Dense internal and sparse external linkages are properties of a cluster. Thus, after estimating the partial correlation matrices by the penalized linear regression, we seek the modular structures of brain networks and observe their differences based on the lobe structures.

7965-43, Session 8

MAP-based denoising of dynamic PET data for quantitative receptor imaging

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We propose a MAP-based denoising method for PET functional imaging. In PET, time activity curves in tissue (tTAC) is analyzed using Logan Graphical Analysis (LGA) as distribution volume (V). In the method, a prior distribution of tTACs is computed based on a set of simulated ones, which are outputs from a compartment model that describes the behavior of administered radioligand in tissue. Drawing a set of rate constants, that is a system parameter of the model, from a uniform distribution covering physiologically feasible range, we can obtain a corresponding simulated tTACs, which compose a manifold in a space of tTACs. Given a measured tTAC, we compute the posterior probability distribution at each point on this manifold. The denoised tTAC is derived as the point on the manifold where the computed posterior probability is the maximum. The purpose of this study was to experimentally analyze the relationship between the prior probability and the resultant estimates of V. For this analysis, we selected [11C]SA4503 as a radioligand and computed three prior probability distributions of the tTACs. Using each of these priors, we denoised a set of synthetic noisy tTACs and a set of clinical ones, and evaluated the estimation errors of V. The results showed that the estimated V became most accurate when the manifold was enough large that the maximum of the posterior probability was never located at the boundary of the manifold.

7965-44, Session 9

Seeing the focus of epilepsy through a hyperspectral camera during neurosurgery

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In epilepsy surgery the focus of epilepsy should be delineated as accurately as possible to minimize damage to critical brain structures. Conventional focus localization techniques include scalp EEG, MEG, SPECT, and PET. These are all indirect methods, i.e. the focus has to be estimated, co-registered to MRI and relocated to the cortex during surgery. In this study we explored the use of a hyper-spectral camera in directly seeing oxygenation changes in the cortex.

An epilepsy patient had recurring seizures every five minutes with tonic spasms in one hand, continuing for 24 hours a day. MR images and intracranial EEG recordings demonstrated seizure onset in the primary motor hand area. After removing the intracranial electrode grid, the exposed cortex was imaged using a hyper-spectral camera mounted to the surgical microscope. During a 7 minute scan, groups of 4 wavelength images were captured at 10 s interval. By calculating the oxy-hemoglobin concentration, a local depletion of oxygen was seen in the motor cortex of the hand, corresponding to the intracranial EEG findings. After multiple subpial transections in this motor area, clinical seizures abated.

Thus, we were able to monitor seizure activity in the cortex by directly observing local oxygen consumption. Although this is a special case with localized and predictable cortical changes, it is proof-of-principle that we can visualize local brain oxygen consumption at high resolution in real-time. This opens prospects of intra-operative function localization of sensory evoked stimuli, or, in the awake patient, of voluntary motor or speech activity.

7965-45, Session 9

A unified approach for high throughput analysis of real-time biomolecular interactions in surface plasmon resonance and fluorescence imaging

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The analysis of real-time biomolecular interactions (observation is performed as the biological interaction occurs) provides information on the formation of target/probe complexes, particularly on their dynamic behaviours. Namely, it allows the determination of the affinity constant, a static value that characterizes the interaction properties, using two dynamic values, the association and dissociation constants. Such dynamic behaviour can be assessed either with surface plasmon resonance (SPR) or fluorescence-based biosensors. The challenging issue is the automatic extraction and analysis of the interaction signal for each spotted probe on the biosensor in a high-throughput framework (hundreds of probes). This paper addresses such issue and develops a unified approach for analyzing the image data provided by the above-mentioned technologies. A mathematical modelling of the image data allowed building-up a virtual biosensor able to simulate biologic experiences related to various possible parameters (level of signal and noise, presence of artefacts, surface functionalization, spotting heterogeneity...). Based on such simulation, a generic and automated approach combining 3D mathematical morphology and spatio-temporal classification is proposed for detecting the interacting probes, segmenting the regions of effective signal, and characterizing the associated affinity constants. The developed method has been assessed both qualitatively and quantitatively on simulated and experimental datasets and showed accurate results (maximum error of 7% for the most difficult cases in terms of noise and surface functionalization).

7965-46, Session 9

Preparation of near-infrared-labeled targeted contrast agents for clinical translation

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Targeted fluorophore-labeled contrast agents are moving toward translation to human clinical diagnostic use. The primary applications for clinical optical imaging are envisioned to be aids in real-time intraoperative surgical resection of tumors and nodal metastases, endoscopy, and lymphovascular imaging.The near-infrared dye IRDye 800CW is frequently used in its N-hydroxysuccinamide (NHS) ester form for labeling biomolecules. To prepare for future clinical use, a toxicity study was performed on male and female Sprague Dawley rats given a single intravenous or intradermal administration of IRDye 800CW carboxylate. Based on hematologic, clinical chemistry, and histopathologic evaluation, single administration of IRDye 800CW carboxylate intravenously at dose levels of 1, 5 and 20 mg/kg or 20 mg/kg intradermally produced no pathological evidence of toxicity. The performance of IRDye 800CW-labeled probes with clinical potential was examined in mouse models. These included Affibodies directed against Her2 and EGFR, a metabolic probe, 2-deoxyD-glucose, and an integrin-specific peptide. All probe types showed good performance in mouse models for detecting either spontaneous tumors or tumor xenografts in vivo. Coupled with instrumentation either currently available or under development, molecular imaging using ligands labeled with IRDye 800CW and targeted to cellular receptors and transporters have the potential to become intraoperative tools for cancer surgery.

7965-47, Session 9

A fast reconstruction method for fluorescence molecular tomography based on improved iterated shrinkage

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Fluorescence molecular tomography (FMT) has become a promising imaging modality for in vivo small animal molecular imaging, and has many successful applications. This is partly due to the wealth of the fluorescent probes. By labeling the regions of interest with fluorescent probes, FMT can achieve non-invasive investigation of the biological process by localizing the targeted probes based on certain inverse mathematical models. However, FMT is usually an ill-posed problem, and some form of regularization should be included to stabilize the problem, which can be considered as the a priori information of the fluorescent probe bio-distribution. When FMT is used for the early detection of tumors, an important characteristic is the sparsity of the fluorescent sources. This is because tumors are usually very small and sparse at this stage. Considering this, general sparsity-promoting Lp-norm regularization is utilized in this paper. The iterated shrinkage based reconstruction method is adopted to solve the general Lp regularization problem. However, the original iterated shrinkage method is proved to have a linear convergence rate, and a large number of iterations are needed to obtain satisfactory results. In this paper, an improved iterated shrinkage based FMT reconstruction algorithm is proposed. By using the solutions from two previous iterations to determine the current solution, the convergence rate can be greatly increased. Heterogeneous simulation experiment shows that the proposed method can obtain comparable results with greatly reduced number of iterations compared with the original iterated shrinkage based method, which makes it a practical reconstruction algorithm.

7965-48, Session 9

A novel method for eliminating autofluorescence of small animals in fluorescence molecular imaging

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As a newly emerged optical imaging method, fluorescence molecular imaging technique has been receiving increasing attention for its ability of non-invasive visualization of the cellular and molecular activities. However, as a kind of background noise, autofluorescence is a major disturbing factor in fluorescence molecular imaging. In this paper, we proposed a novel method to eliminate autofluorescence of small animals. The method is based on the fact that most autofluorescent signal has a broad excitation and emission spectrum, whereas specific fluorescent probe has a narrow one. First, two fluorescent images are obtained at two different excitation wavelengths. Then we divide the two obtained fluorescent images into blocks with the size of 8×8 pixel. The two blocks from the same position of the two different images respectively constitute a block pair. The ratio of one block's summation of total pixel value to that of ther other block belonging to the same block pair is calculated. After that, we classify all block pairs into fluorescent and non-fluorescent ones by ratio. The former are considered to be actual fluorescent regions. In next step, we adopt an adaptive cluster analysis method to classify all fluorescent block pairs into multiple interest regions. A general centroid algorithm is then applied to locate the center of each interest regions. We recover the interest regions using flood filling algorithm. Finally, we choose a GFP-transfected tumor mouse model and a GFP-transplanted mouse skin model to validate our algorithm.

7965-49, Session 9

Quantitative analysis of tumor matrix patterns through statistical and topological texture features

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The tumor extracellular matrix has been focused on by newer approaches to cancer therapy owing to its important functions in the process of drug delivery and cellular metastasis. This study aims to characterize tumor extracellular matrix structures in the presence and absence of therapy, as observed on second harmonic generation (SHG) images through both gray-level co-occurrence matrix (GLCM) derived texture features as well as Minkowski Functionals (MF) that focus on the underlying gray-level topology and geometry of the texture patterns. Thirteen GLCM texture features and three MF texture features were extracted from 119 regions of interest (ROI) annotated on SHG images of treated and control samples of tumor extracellular matrix. These texture features were then used in a machine learning task to classify ROIs as belonging to treated or control samples. A fuzzy k-nearest neighbor classifier was optimized using random sub-sampling cross-validation for each texture feature and the classification performance was calculated on an independent test set using the area under the ROC curve (AUC); AUC distributions of different features were compared using a Mann-Whitney U-test. Two GLCM features f3 and f13 exhibited a significantly higher classification performance than other GLCM features ($p < 0.05$). The MF feature Area exhibited the best classification performance among the MF features while also being comparable to that obtained with the best GLCM features. These results show that both statistical and topological texture features can be used as quantitative measures is evaluating the effects of therapy on the tumor extracellular matrix.

7965-50, Session 10

Time evolution and hemodynamics of cerebral aneurysms

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Cerebral aneurysm rupture is a leading cause of hemorrhagic strokes. Because they are being more frequently diagnosed before rupture and the prognosis of subarachnoid hemorrhage is poor, clinicians are often required to judge which aneurysms are prone to progression and rupture. Unfortunately, the processes of aneurysm initiation, growth and rupture are not well understood. Multiple factors associated to these processes have been identified. Our goal is to investigate two of them, arterial hemodynamics and the peri-aneurysmal environment, by studying a group of growing cerebral aneurysms that are followed longitudinally in time using computational fluid dynamics.

Five patients with unruptured untreated brain aneurysms which exhibited growth during the observation period were selected for the study. Vascular models of each aneurysm at each observation time were constructed from the corresponding computed tomography angiography (CTA) images. Subsequently, models were aligned, and geometrical differences quantified. Blood flow was modeled with the 3D unsteady incompressible Navier-Stokes equation for a Newtonian fluid, and wall shear stress distribution and flow patterns were calculated and visualized.

Analysis of the simulations and changes in geometry revealed asymmetric growth patterns and suggests that areas subject to vigorous flows, i.e. relative high wall shear stress and concentrated streamlines patterns; correspond to regions of aneurysm growth. Furthermore, the geometrical evolution of aneurysms is clearly affected by contacts with bone structures and calcifications in the wall, and as a consequence the hemodynamics is greatly modified. Thus, the peri-aneurysmal

environment could greatly affect the hemodynamics and must be considered when analyzing aneurysm evolution.

7965-51, Session 10

Study of stent deployment mechanics using a high-resolution x-ray imaging detector

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To treat or prevent some of the 795,000 annual strokes in the U.S., self-expanding endo-vascular stents deployed under fluoroscopic image guidance are often used. Neuro-interventionalists need to know the deployment behavior of each stent in order to place them in the correct position. Using the Micro-Angiographic Fluoroscope (MAF) which has about 3 times higher resolution than commercially available flat panel detectors (FPD) we studied the deployment mechanics of two of the most important commercially available nitinol stents: the Pipeline embolization device (EV3), and the Enterprise stent (Codman). The Pipeline stent's length extends to about 3 times that of its deployed length when it is contained inside a catheter. From the high-resolution images with the MAF we found that upon the sudden release of the distal end of the Pipeline from a helical wire cap, the stent expands radially but retracts to about 30% (larger than for patient deployments) of its length. When released from the catheter proximally, it retracts additionally about 50% contributing to large uncertainty in the final deployed location. In contrast the MAF images clearly show that the Enterprise stent self expands with minimal length retraction during deployment from its catheter and can be retrieved and repositioned until the proximal markers are released from clasping structures on its guide-wire thus enabling more accurate placement at the center of an aneurysm or stenosis. The high-resolution imaging demonstrated in this study should help neurointerventionalists understand and control endovascular stent deployment mechanisms and hence perform more precise treatments.

7965-52, Session 10

Angiographic imaging evaluation of patient-specific bifurcation-aneurysm phantom treatment with pre-shaped, self-expanding, flow-diverting stents: feasibility study

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Aneurysm treatment using flow diversion could become the treatment of choice in the near future. While such side-wall aneurysm treatments have been studied in many publications and even implemented in selected clinical cases, bifurcation aneurysm treatment using flow diversion has not been addressed in detail. Using angiographic imaging, we evaluated treatment of such cases with several stent designs using patient-specific aneurysm phantoms. The aim is to find a way under fluoroscopic image guidance to place a low-porosity material across the aneurysm orifice while keeping the vessel blockage minimal. Three pre-shaped self-expanding stent designs were developed: the first design uses a middle-flap wing stent, the second uses a two-tapered-wing-ended stent, and the third is a slight modification of the first design in which the middle-flap is anchored tightly against the aneurysm using a standard stent. Treatment affects on flow were evaluated using high-speed angiography (30 fps) and compared with the untreated aneurysm. Contrast inflow was reduced in all the cases: 25% for Type 1, 63% for type 2 and 88% for Type 3. The first and the second stent design allowed some but substantially-reduced flow inside the aneurysm neck as indicated by the time-density curves. The third stent design eliminated almost all flow directed at the aneurysm dome, and only partial filling was observed. The results are quite promising and warrant future study.

7965-53, Session 10

Comparison of models and acquisition techniques for estimation of myocardial blood flow from CT

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Dynamic contrast enhanced CT has been successfully applied in cardiac imaging for the estimation of myocardial blood flow (MBF). In general, these acquisitions impart a relatively high radiation dose because they require continuous or gated imaging the heart for 15-40 seconds. At present, there is no consensus on the appropriate estimation method to derive MBF and on the appropriate acquisition technique to minimize dose while maintaining MBF estimation accuracy and precision. This work explores the tradeoff of accuracy and precision of MBF estimates with several estimation methods and acquisition techniques in support of the fundamental goal of optimizing dynamic cardiac CT in terms of radiation dose and MBF estimation fidelity. We simulated time attenuation curves (TACs) for a range of flow states (Flow = [0.8, 1.6, 2.4, 3.2] ml/g/min) and several acquisition techniques. We estimated MBF with 5 different methods for each simulated TAC. From multiple independent realizations, we assessed the accuracy and precision of each method. Results show that acquisition techniques with 1/3 tube current or 1/3 temporal sampling permits accurate MBF estimates with most methods with reduction in MBF estimate precision by on average 30%. Furthermore, reduction in model complexity can be beneficial for improving the precision of MBF estimates.

7965-54, Session 10

Developing a tool for the validation of quantitative DCE-MRI

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Dynamic Contrast-Enhanced Magnetic Resonance Imaging (DCE-MRI) is becoming an indispensable tool to non-invasively study tumor characteristics. However, many different DCE-analysis methods are used, varying in modelling approach, arterial input function estimation, calibration methods and parameter choices. To compare and validate the different methods, histology is the gold standard. For this purpose, exact co-localization between histology and MRI images is a prerequisite, but complex and requires precise and meticulous effort. In this study a tool is developed to validate quantitative DCE-data with histology and emphasis is placed on correct registration of histology. A pancreatic tumor (CA20948 tumor) was grown in a rat model. The tumor was dissected after MR imaging, embedded in paraffin, and cut into thin slices. These slices were stained with haematoxylin and eosin, digitized and stacked in a 3D volume. Next, the 3D histology was registered to ex-vivo SWI-weighted MR images, which in turn were registered to in-vivo SWI and DCE images. This way co-localization between DCE-MRI and 3D histology was achieved. Semi-quantitative and quantitative parameters were calculated. For the evaluation, regions of interest were drawn in histology slices and transformed to the DCE-parameter maps, from which mean and standard deviation were calculated. Preliminary results suggest that both pharmacokinetic and some heuristic DCE-parameters can discriminate between vital and non-vital regions. The developed method offers the basis for an accurate spatial correlation of DCE-MRI derived parametric maps and histology. In future, this method will be expanded to include different DCE-MRI analysis methods, AIF estimation procedures and different histology stains.

7965-55, Session 11

The effect of PSF spatial-variance and nonlinear transducer geometry on motion estimation from echocardiography

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Cardiovascular diseases are among the leading causes of mortality and morbidity in the western world and two-dimensional echocardiography is still the most widely used modality for the assessment of cardiac function. Echocardiographic series are derived from the mechanical interaction between the ultrasound field and the contractile heart tissue. Previously, we combined a 3-D left-ventricular kinematic model and an US model in order to produce realistic B-mode echocardiographic images. In the present contribution, several simple and complex cardiac motions such as translation in axial and horizontal direction, scaling, and out-of-plane motions are considered in order to determine the effect of the spatial variance of the Ultrasonic field point-spread function in the estimated motion fields regardless of motion estimation technique that is adopted.

The simulator simulates both the spatial variance of the PSF (Point Spread Function) as well as the convex transducer geometry. The importance of the cardiac US simulator is that it provides both echocardiographic images as well as actual ground-truth vector field of material point deformations. In our development, simulated echocardiographic slices are filled with the cardiac texture derived from a post-mortem heart biopsy. Scatterers are distributed according to the intensity of post-mortem slice.

Our results indicate that transducer geometry and PSF (Point Spread Function) spatial-variance induces errors in the motion estimation methods which are greater in the lateral regions of the image for the axial displacements.

Moreover, we present a detailed description of the validation of several optical flow techniques including block matching for simple as well as complex cardiac scatterer motions.

7965-56, Session 11

Carbon nanotube based respiratory gated micro-CT imaging of a murine model of lung tumors with optical imaging correlation

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Current optical imaging techniques can successfully measure tumor load in murine models of lung carcinoma but lack structural detail. We demonstrate that respiratory gated micro-CT imaging of such models gives information about structure and correlates with tumor load measurements by optical methods.

Four mice with multifocal, Kras-induced tumors expressing firefly luciferase were imaged against four controls using both optical imaging and respiratory gated micro-CT. CT images of anesthetized animals were acquired with a custom CNT-based system using 30 ms x-ray pulses during peak inspiration; respiration motion was tracked with a pressure sensor beneath each animal's abdomen. Optical imaging based on the Luc+ signal correlating with tumor load was performed on a Xenogen IVIS Kinetix.

Micro-CT images were post-processed using Osirix, measuring lung volume with region growing. Diameters of the largest three tumors were measured. Relationships between tumor size, lung volumes, and optical signal were compared.

CT images and optical signals were obtained for all animals at two time points. In all lobes of the Kras+ mice in all images, tumors were visible; the smallest to be readily identified measured approximately 300 microns diameter. CT-derived tumor volumes and optical signals related linearly, with r=0.94 for all animals. When derived for only tumor bearing animals, r=0.3. The trend of each individual animal's optical signal tracked correctly based on the CT volumes. Interestingly, lung volumes also correlated positively with optical imaging data and tumor volume burden, suggesting active remodeling.

Gated respiratory micro-CT appears superior to optical techniques for tracking tumor volume, especially across subjects.

7965-57, Session 11

A fully automated method for segmenting lung airway wall area measurements from bronchoscopic Optical Coherence Tomography images

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Chronic Obstructive Pulmonary Disease (COPD), affects almost 600 million people, is currently the fourth leading cause of death worldwide, and continues to grow in prevalence and mortality rates. COPD is an umbrella term for changes in the lung parenchyma (alveolar ducts and bronchioles) and airways, the sum of which result in decreased expiratory flow, dyspnea and gas trapping. Currently, computed tomography (CT) is the clinical mainstay for COPD imaging. CT provides excellent spatial and temporal resolution for quantitative tissue measurements, but dose limitations also result in technological limitations for resolving lung airway dimensions. To address this limitation, we are piloting the use of bronchoscopic Optical Coherence Tomography (OCT), by exploiting the superior spatial resolution of 5-15 micrometers for in vivo airway imaging. Previously, manual segmentation of OCT airway lumen and wall was reported but manual methods are time consuming and prone to observer variability. Therefore, our objective was to develop a fully automated method for segmenting OCT airways and here we explore several different methods of image reconstruction, clustering and post-processing. Our resultant automated method divides the reconstructed image to four clusters using K-means or Fuzzy c-means. A series of rules and algorithms (i.e. cluster selection, artifact removal, de-noising) was applied to process the clustering results in order to segment airway wall area. The results show that our method provides a way to segment and reproducibly measure airway lumen and wall area.

7965-58, Session 11

Imaging of myocardial infarction using carbon nanotube micro-computed tomography and delayed contrast enhancement

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We demonstrate the application of our cardiac and respiratory gated carbon nanotube (CNT) micro-CT system by evaluating murine myocardial infarction models with a delayed contrast enhancement technique.

Myocardial infarction was induced in 8 wild-type male mice. The ischemia reperfusion model was achieved by surgical occlusion of the LAD artery for 30 minutes followed by 24 hours of reperfusion. Free-breathing subjects were anesthetized with isoflurane during imaging. Respiratory and cardiac signals were monitored externally to gate the scan. Micro-CT

data was obtained at 50kV, 3mA cathode current for 15ms per projection. All images were acquired during end exhalation at either 0msec or 55msec after the R-wave (diastole or systole, respectively). Following administration of Omnipaque 300mgI/mL at 0.1ml/5g, images were obtained at 0msec after the R-wave. Fenestra VC was then administered at a 0.1ml/5g dose, followed by images 0 and 55msec after the R-wave. Hearts were then harvested, sliced 1mm thick and stained with TTC.

All eight animals survived surgery and imaging; all demonstrated obvious delayed contrast enhancement in the left ventricular wall in Omnipaque images . Fenestra VC revealed cardiac functional changes quantified by low ejection fractions. All subjects demonstrated areas of myocardial infarct in the LAD distribution on both TTC staining and CNT micro-CT imaging.

CNT enabled gated cardiac micro-CT imaging demonstrates the ability to consistently identify areas of myocardial infarct in mice, providing a powerful tool for the study of cardiovascular biology. Further work is ongoing to streamline the imaging protocol and perform more quantitative analysis of the images.

7965-60, Session 11

Human pulmonary acinar airspace segmentation from three-dimensional synchrotron radiation micro CT images of the secondary pulmonary lobule

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The lung consists of numerous anatomic units smaller than a lobe or segment. The alveolated structure in the acinus plays an important role in gas exchange function. Three-dimensional (3-D) analysis of the acinus region is fundamental to understanding the structure-function relationship. However, only a limited number of attempts have been conducted because of technical limitations for microstructural imaging. This paper aims for a 3-D microstructural analysis of the pulmonary acinus with isotropic spatial resolution in the range of several micrometers by using micro CT. Previously, we demonstrated the ability of synchrotron radiation micro CT (SRμCT) using offset scan mode in microstructural analysis of the whole part of the secondary pulmonary lobule. In this paper, we present a semi-automatic method to segment the acinar and subacinar airspaces from the secondary pulmonary lobule imaged by the SRμCT. The method began with a segmentation of the tissues such as pleural surface, interlobular septa, alveola wall, or vessel using threshold technique and 3-D connected component analysis. Follow-on stages then constructed 3-D air space separated by tissues and represented branching patterns of airways and airspaces distal to the terminal bronchiole. Finally, a graph-partitioning approach isolated acini whose stems were interactively defined as the terminal bronchiole in the secondary pulmonary lobule. Additionally, the isolated acinar airspace was segmented into subacini in which the first respiratory airway was considered as the stem using the graph-partitioning approach. Results demonstrate that the proposed method can extract several acinar airspaces from the 3-D SRμCT image of secondary pulmonary lobule and that the extracted acinar airspace enable an accurate quantitative description of the anatomy of the human acinus for interpretation of the basic unit of pulmonary structure and function.

7965-66, Session 11

Automated pulmonary ventilation imaging (APVI) for children using Xe-133 scintigraphy

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Dynamic lung scintigraphy is an important clinical tool to assess pediatric pulmonary ventilation since single-breathing scintigraphy requires a number of respiratory maneuvers, such as breath-holding, which are impractical for young children. Conventional methods for the quantitative assessment of pulmonary ventilation are based on the analysis of global (left/right lung regions) time activity curves or regional (upper/middle/lower three regions for each lung) activity curves. In this study, automated pulmonary ventilation imaging (APVI) was developed to quantitatively assess the ventilation in pediatric lungs using dynamic Xe-133 scintigraphy. APVI is a computerized software algorithm that measures ventilation by tracking the changes of each pixel in a dynamic series of images to generate three arrays of parameters: washout halftime, residual percentage and washout clearance rate. Then the three arrays of parameter are mapped into color images using a look-up table (LUT) to give an intuitive presentation of pulmonary ventilation. APVI consists of a series of image/signal processing to automate the ventilation quantification in lung regions, including, image preprocessing, lung region segmentation, phases (wash-in, equilibrium and washout) segmentation, and ventilation quantification. APVI provides intuitive images of ventilation measurement to highlight the detection of obstructive lung diseases. APVI has been applied in lung Xe-133 ventilation studies for two years at Children's Hospital Boston as a visual tool for clinical decision support in assessing ventilation function of children lungs.

7965-61, Session 12

Differential spatial activity patterns of acupuncture by a machine learning based analysis

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Acupoint specificity, lying at the core of the Traditional Chinese Medicine, underlies the theoretical basis of acupuncture application. However, recent studies have reported that acupuncture stimulation at nonacupoint and acupoint can both evoke similar signal intensity decreases in multiple regions. And these regions were spatially overlapped. This does not support the notion of acupoint specificity. In their studies, typical block-based General Linear Model (GLM) method and a multi-block experimental paradigm were generally applied to identify the neural substrate for acupuncture effects. GLM is a model-based data analysis method, predicting the temporal changes in the blood oxygenation level-dependent (BOLD) signal conforming to the "on-off" specifications. However, since it has been proved that acupuncture effects can sustain even beyond acupuncture needling being terminated. It might be inappropriate to use "on-off" specifications to model the time course of changes in signal intensity evoked by acupuncture. In the current study, we used a data-driven based Support Vector Machine (SVM) approach to elucidate the specific neural response pattern induced by acupuncture stimulation. Group analysis demonstrated that stimulation at two different acupoints (belong to the same nerve segment but different meridians) could elicit distinct neural response patterns. Our findings may provide evidence for acupoint specificity.

7965-62, Session 12

The distributed neural system for top-down letter processing: an fMRI study

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This fMRI study used Psychophysiological interaction (PPI) to investigate top-down letter processing with an illusory letter detection task. After an initial training that became increasingly difficult, participant was instructed to detect a letter from pure noise images where there was actually no letter. Such experimental paradigm allowed for isolating top-down components of letter processing and minimizing the influence of

bottom-up perceptual input. A distributed cortical network of top-down letter processing was identified by analyzing the functional connectivity patterns of letter-preferential area (LA) within the left fusiform gyrus. Such network extends from the visual cortex to high level cognitive cortexes, including the left middle frontal gyrus, left medial frontal gyrus, left superior parietal gyrus, bilateral precuneus, and left inferior occipital gyrus. These findings suggest that top-down letter processing contains not only regions for processing of letter phonology and appearance, but also those involved in decision making and memory processing.

7965-63, Session 12

Real-time fMRI data analysis using region of interest selection based on fast ICA

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Real-time functional magnetic resonance imaging (rtfMRI) is a new technique which can present (feedback) brain activity during scanning. Through fast acquisition and online analysis of BOLD signal, fMRI data are processed within one TR. Current rtfMRI provides an activation map under specific task mainly through the GLM analysis to select region of interest (ROI). This study was based on independent component analysis (ICA) and used the result of fast ICA analysis to select the node of the functional network as the ROI. Real-time brain activity within the ROI was presented to the subject who needed to find strategies to control his brain activity. The whole real-time processes involved three parts: pre-processing (including head motion correction and smoothing), fast ICA analysis and feedback. In addition, the result of fast head motion correction was also presented to the experimenter in a curve diagram. Based on the above analysis processes, a real time feedback experiment with a motor imagery task was performed. An overt finger movement task as localizer session was adopted for ICA analysis to get the motor network. Supplementary motor area (SMA) in such network was selected as the ROI. During the feedback session, the average of BOLD signals within ROI was presented to the subjects for self-regulation under a motor imagery task. In this experiment, TR was 1.5 seconds, and the whole time of processing and presentation was within 1 second. Experimental results not only showed that the SMA was controllable, but also proved that the analysis method was effective.

7965-64, Session 12

The application of independent component analysis with projection method to two-task fMRI data over multiple subjects

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Spatial Independent component analysis (sICA) has been successfully used to analyze functional magnetic resonance (fMRI) data. However, the application of ICA was limited in multi-task fMRI data due to the potential spatial dependence between task-related components. Long et al. (2009) proposed ICA with linear projection (ICAp) method and demonstrated its capacity to solve the interaction among task-related components in multi-task fMRI data of single subject. However, it's unclear that how to perform ICAp over a group of subjects. In this study, we proposed a group analysis framework on multi-task fMRI data by combining ICAp with the temporal concatenation method reported by Calhoun (2001). The results of real fMRI experiment containing multiple visual processing tasks demonstrated the feasibility and effectiveness of the group ICAp method. Moreover, compared to the GLM method, the group ICAp method is more sensitive to detect the regions specific to each task.

7965-65, Session 12

The functional alterations associated with motor imagery training: a comparison between motor execution and motor imagery of sequential finger tapping

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Motor imagery training, as an effective strategy, has been more and more applied to neurological disorders rehabilitation and motor skill learning. Studies on the neural mechanism underlying motor imagery have suggested that such effectiveness may be related to the functional congruence between motor execution and motor imagery. However, as compared to the studies on motor imagery, the studies on motor imagery training are much fewer. The functional alterations associated with motor imagery training and the effectiveness of motor imagery training on motor performance improvement still need further investigation. Using fMRI, we employed a sequential finger tapping paradigm to explore the functional alterations associated with motor imagery training in both motor execution and motor imagery tasks. We hypothesized through 14 consecutive days motor imagery training, the motor performance could be improved and the functional congruence between motor execution and motor imagery would be sustained form pre-training phase to post-training phase. Our results confirmed the effectiveness of motor imagery training in improving motor performance and demonstrated that in both pre and post-training phases, motor imagery and motor execution consistently sustained the congruence in functional neuroanatomy, including SMA(supplementary motor cortex), PMA(premotor area), M1(primary motor cortex) and cerebellum. Moreover, for both execution and imagery tasks, a similar functional alteration was observed in fusiform gyrus through motor imagery training. These findings provided an insight into the effectiveness of motor imagery training and suggested its potential therapeutic value in motor function rehabilitation.

Conference 7966: Image Perception, Observer Performance, and Technology Assessment

Wednesday-Thursday 16-17 February 2011 • Part of Proceedings of SPIE Vol. 7966 Medical Imaging 2011: Image Perception, Observer Performance, and Technology Assessment

7966-01, Session 1

Optimizing presentation of breast tomosynthesis image volumes using eye tracking combined with a free response human observer study

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The purpose of this study was to evaluate four different image presentation procedures as part of improving viewing conditions of breast tomosynthesis (BT) image volumes. The procedures consisted of free scroll volume browsing, and a combination of initial volume loops at three different frame rates (25, 14 and 9 slices/s) terminated upon request followed by free scroll volume browsing. Fifty-five normal BT image volumes in MLO view were collected. In these, simulated lesions (20 masses and 20 clusters of microcalcifications) were randomly inserted, creating four unique image sets for each procedure. Four readers interpreted the cases in a random order. The task was to locate the lesions, mark and assign a five level confidence scale. Visual search patterns, time spent on search, decisions and ratings were recorded using a tower mounted eye tracking system. The diagnostic accuracy was analyzed using Jackknife Free Receiver Operating Characteristics (JAFROC). Visual search parameters (time-to-hit lesion, dwell time, revisitations, decision and total analyze time) were also analyzed. Results indicate there was no statistically significant difference in JAFROC FOM between the different viewing procedures, however the total analyze time spent per case was significantly reduced in the free scroll volume browsing procedure.

7966-02, Session 1

Assessment of breast density: reader performance using synthetic mammographic images

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The quantity and appearance of dense breast tissue in mammograms is related to the risk of developing breast cancer. It also has an impact on sensitivity of mammographic interpretation, likelihood of recall following routine screening, performance of computer-aided detection and local recurrence of cancer following surgery. Visual assessment of breast density is widely used, often with readers indicating the percentage of dense tissue in a mammogram.

Although real mammograms can be used to investigate intra- and inter-observer variability, ground truth is difficult to ascertain, so to investigate reader accuracy, we created 60 synthetic, mammogram-like images with densities comparable in area to those found in screening. Half the images contained a single dense area, and the remainder had multiple or linear densities. In half of the single density images, breast size was varied. The images were randomized and assessed by 9 expert and 6 non-expert readers who marked percentage area of density on a visual analogue scale.

The non-expert readers' estimates of percentage area of density were closer to the truth (6-11% average deviation) than the experts' estimates (10-19%), with only one expert matching the performance of the least accurate non-expert. The readers were most accurate when the density formed a single area in the image, and least accurate when the dense area was composed of linear structures. In almost every case, the dense area was overestimated by the expert readers. When experts were ranked according to the degree of overestimation, this reflected their relative performance on real mammograms.

7966-03, Session 1

Health professionals' agreement on density judgements and successful abnormality identification within the UK Breast Screening Programme

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Higher breast density is associated with a greater chance of developing breast cancer. Additionally, it is well known that higher mammographic breast density is associated with increased difficulty in accurately identifying breast cancer. However, little is known of the reliability of breast density judgements. All UK breast screeners (primarily radiologists and technologists) annually participate in the PERFORMS self-assessment scheme where they make several judgements about series of challenging recent screening cases of known outcomes. As part of this process, for each case, they provide a radiological assessment of the likelihood of cancer on a confidence scale, alongside an assessment of case density using a three point scale. Analysis of the data from two years of the scheme (namely, 444 participants who examined 209 cases) found that the degree of agreement on case density was significantly greater than no agreement ($p < .001$). However, only a moderate degree of inter-rater reliability was exhibited (= .44) with significant differences between the occupational groups. The reasons for differences between the occupational groups and the relationship between agreement on density rating and case reading ability are explored.

7966-04, Session 1

The time course of cancer detection performance

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The purpose of this study was to measure how mammography readers' behaviour and performance varies as a reading session progresses.

Method: To measure changes in behaviour eight qualified mammography readers were video-taped for four 45 minute sessions each during their routine mammography reading. The time taken per case and whether the participants looked at the prior mammograms was recorded for each case from the video-tape. To measure changes in performance eight qualified mammography readers 160 difficult test cases twice. The participants rated the probability of malignancy of each case, and whether they would recall the woman for further tests. These sessions were also videotaped to measure whether behaviour in the experiment was the same as in screening practice.

Results: In screening practice time taken per case ($r=-.41$, $p=.03$) and proportion of cases for which the prior mammogram was looked at ($r=-.37$, $p<.04$) decreased as the reading session progressed. In the experiment the same pattern was observed. Performance improved as the session progressed, with a decrease in probability of malignancy score for normal cases.

Conclusions: Performance and behaviour were found to change as the reading session progresses, and therefore more research is needed to understand how the length of a reading session may affect cancer detection performance.

7966-05, Session 1

Can horizontally oriented breast tomosynthesis image volumes or the use of a systematic search strategy improve interpretation? An eye tracking and free response human observer study.

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Our aim was to evaluate if there is a benefit in diagnostic accuracy and efficiency of viewing breast tomosynthesis (BT) image volumes presented horizontally oriented, but also to evaluate the use of a systematic search strategy where the breast is divided, and analyzed consecutively, into two sections (upper and lower). These image presentations were compared to regular vertical presentations. All methods were investigated using procedures consisting of free scroll volume browsing, and a combination of initial volume loops at three different frame rates (25, 14 and 9 slices/s) terminated upon request followed by free scroll volume browsing. Fifty-five normal BT image volumes in MLO view were collected. In these, simulated lesions (20 masses and 20 clusters of microcalcifications) were randomly inserted, creating four unique image sets for each procedure. Four readers interpreted the cases in a random order. The task was to locate the lesions, mark and assign a five level confidence scale. Visual search patterns, time spent on search, decisions and ratings were recorded using a tower mounted eye tracking system. The diagnostic accuracy was analyzed using Jackknife Free Receiver Operating Characteristics (JAFROC). Visual search parameters (time-to-hit lesion, dwell time, revisitations, decision and total analyze time as well as velocity and direction of saccades) were also analyzed. Results indicate there was no statistically significant difference in JAFROC FOM between the different image presentation procedures, although visual search was more time efficient when viewing horizontally oriented image volumes. The systematic search strategy seemed to be beneficial, especially using the free-scroll mode.

7966-06, Session 2

Modeling error in assessment of mammographic image features for improved computer-aided mammography training: initial experience

M. A. Mazurowski, G. D. Tourassi, Duke Univ. (United States)

In this study we investigate the hypothesis that there exist patterns in erroneous assessment of BI-RADS image features among radiology trainees when performing diagnostic interpretation of mammograms. We also investigate whether these error making patterns can be captured by individual user models. To test our hypothesis we propose a user modeling algorithm that uses the previous readings of a trainee to identify whether certain BI-RADS feature values (e.g. “spiculated” value for “margin” feature) are associated with higher than usual likelihood that the feature will be assessed incorrectly. In our experiments we used readings of 3 radiology residents and 7 breast imaging experts for 33 breast masses for the following BI-RADS features: parenchyma density, mass margin, mass shape and mass density. The expert readings were considered as the gold standard. Rule-based individual user models were developed and tested using the leave one-one-out scheme. Our experimental evaluation showed that the individual user models are accurate in identifying cases for which errors are more likely to be made. The user models captured regularities in error making for all 3 residents. This finding supports our hypothesis about existence of individual error making patterns in assessment of mammographic image features using the BI-RADS lexicon. Explicit user models identifying the weaknesses of each resident could be of great use when developing and adapting a personalized training plan to meet the resident’s individual needs. Such approach fits well with the framework of adaptive computer-aided educational systems in mammography we have proposed before.

7966-07, Session 2

Does the time of day affect radiologists’ performance in digital mammography reporting?

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Mammographic image reporting accuracy among radiologists varies. The study examines whether radiologists’ digital image reading performance varies at different times throughout the day. Observers comprised of 69 experienced breast radiologists who reviewed 50 mammograms, consisting of 4 images each, of which 15 were abnormal. All the observers were grouped and assigned a specific hour, starting from 7:00am to 7:00pm, to detect the lesion if present and mark the confidence rating (1-5) in the booklet provided. Demographic details of all the participating radiologists were recorded in terms of age, experience and number of mammographic readings per year. Radiologists’ performance was measured and compared in terms of sensitivity, specificity and receiver operating characteristic (ROC) scores. Using Spearman methods, correlation analyses were performed. A p value of less than or equal to 0.05 was considered significant. In terms of mean ROC scores no significant differences ($p \geq 0.42$) were found between groups performing at different time of the day. Also, no significant differences were noted for sensitivity ($p \geq 0.97$) and specificity ($p \geq 0.43$) when groups were compared with each other. The findings from the study suggest that although radiologists’ performance varies slightly throughout the day, the exact time of day has no significant effect on radiologists’ digital mammographic image reading performance. The result may be beneficial for breast radiologists as they read mammographic images at different times throughout the day.

7966-08, Session 2

Effect of learning with feedback on the detectability of pulmonary nodules in chest tomosynthesis

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In chest tomosynthesis, low-dose projections collected over a limited angular range are used for reconstruction of section images of the chest, resulting in a reduction of the disturbing anatomy at a moderate increase in radiation dose compared to chest radiography. In a previous study, we investigated the effects of learning with feedback on the detection of pulmonary nodules in chest tomosynthesis. Six observers with varying degrees of experience of chest tomosynthesis analyzed 89 tomosynthesis cases for presence of pulmonary nodules. The 89 cases

were analyzed before and after learning with feedback, which included a collective learning session at which the observers were shown their analysis of another set of cases. Multidetector computed tomography (MDCT) was used as reference. The differences in performance between the two readings were calculated using the jackknife alternative free-response receiver operating characteristics (JAFROC-2) as primary measure of detectability. Significant differences between the readings were found only for observers inexperienced in chest tomosynthesis. The purpose of the present study was to extend the statistical analysis of the results of the previous study, including JAFROC-1 and FROC curves in the analysis. Preliminary results are consistent with the results of the previous study, but JAFROC-1 gave higher significance than JAFROC-2 for the observers who improved their performance after learning with feedback.

7966-09, Session 2

Classification of radiological errors in chest radiographs using a support vector machine on the spatial frequency features of false-negative and false-positive regions

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Aim: To optimize automated classification of radiological error responses (either false-negative, FN, or false-positive, FP) of the most dwelled locations in PA Chest Radiographs using a Support Vector Machine on the spatial frequency features extracted from the local background of selected regions.

Background: The majority of the unreported pulmonary nodules are visually detected but not recognized; shown by the prolonged dwell time values at false-negative regions. Similarly, overestimated nodule locations are capturing substantial amounts of foveal attention. Spatial frequency properties of selected local backgrounds have been shown to be correlated with human observer responses ether in terms of accuracy in indicating abnormality position or in the precision of visual sampling the medical images.

Methods: Eight radiologists participated in the eye tracking experiments conducted under conditions of pulmonary nodule detection from a set of 30 Posterior-Anterior Chest Radiographs (CxR). The accuracy of responses was analysed according to ground truth information. The most dwelled locations have been identified and subjected to Spatial Frequency (SF) analysis. The image-based features of selected ROI were extracted with un-decimated Wavelet Packet Transform. An analysis of variance was run to select SF features. A Support Vector Machine (SVM) schema was implemented to classify FN and FP from all ROI.

Results: A relative high overall sensitivity and moderately low specificity was obtained for a Wavelet-SVM algorithm operating on individual cases, with 88% average correct ratio for FN and FP recognition from all prolonged dwell locations.

Conclusion: The preliminary results show, that the SVM can be used for classification of FN and FP in all the most attractive locations of prolonged dwell. The work is still in progress and not all analytical procedures have been completed, which might have an effect on the specificity of the algorithm.

7966-10, Session 2

A novel platform to simplify human observer performance experiments in clinical reading environments

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Although human observer performance experiments (HOPE) are frequently carried out in controlled environments, this doesn't truly reflect real clinical reading conditions. Often during HOPE, the amount of ambient reading variables is kept as low as possible and this is contrasting with the dynamic nature of a clinical reading environment. The aim of current work was to extend our previously developed software platform Sara² to perform HOPE, to better take into account the influences of the reading environment. Generic modules for ROC, LROC, FROC, M-AFC and VGA/IQC experiments were developed together with additional modules for finding unexpected interruptions due to clinical emergencies by means of idle time and mouse trajectory monitoring. Also a generic approach towards the inclusion of reading questionnaires and a RFID enabled secured login system was added. We created a sensor network consisting out of-the-shelf components which continuously could monitor ambient reading conditions like: temperature, ambient lighting, humidity, sound levels and observer reading distance. Finally we included a link to incorporate the use of specialized 3rd party PACS viewers in our software framework. Using the proposed software and hardware solution, we could simplify the setup and the performing of HOPE in clinical reading environments.

7966-11, Session 2

Analysis of physiological impact while reading stereoscopic radiographs

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A stereoscopic viewing technology is expected to improve diagnostic performance in terms of reading efficiency by adding one more dimension to the conventional 2D images. Although a stereoscopic technology has been applied to many different field including TV, movies and medical applications, physiological fatigue through reading stereoscopic radiographs has been concerned although no established physiological fatigue data have been provided. In this study, we measured the -amylase concentration in saliva, heart rates and normalized tissue hemoglobin index (nTHI) in blood of frontal area to estimate physiological fatigue through reading both stereoscopic radiographs and the conventional 2D radiographs. In addition, subjective assessments were also performed.

As a result, the pupil contraction occurred just after the reading of the stereoscopic images, but the subjective assessments regarding visual fatigue were nearly identical for the reading the conventional 2D and stereoscopic radiographs. The -amylase concentration and the nTHI continued to decline while examinees read both 2D and stereoscopic images, which reflected the result of subjective assessment that almost half of the examinees reported to feel sleepy after reading. The subjective assessments regarding brain fatigue showed that there were little differences between 2D and stereoscopic reading.

In summary, this study shows that the physiological fatigue caused by stereoscopic reading is equivalent to the conventional 2D reading including ocular fatigue and burden imposed on brain.

7966-12, Session 3

Incorporating holistic search into a SPECT myocardial perfusion imaging numerical observer

J. M. O'Connor, H. C. Gifford, Univ. of Massachusetts Medical School (United States); J. G. Brankov, Illinois Institute of Technology (United States); P. H. Pretorius, Univ. of Massachusetts Medical School (United States)

Previous Single Photon Emission Computed Tomography (SPECT) myocardial perfusion imaging (MPI) research has explored the utility

of numerical observers. One recent study proposed that holistic visual search of a myocardial perfusion image by an expert human observer might inform the development of the model for a SPECT MPI numerical observer. Further examination of numerical processing techniques that seem to be analogous to human holistic image interpretation helps to further refine the numerical observer. The current state of the numerical observer considers two fundamental steps: clustering and selection of suspicious defect sites. This work examines various selection methods for the purpose of enhancing our numerical observer.

7966-13, Session 3

Channelized relevance vector machine as a numerical observer for cardiac perfusion defect detection task

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In this paper, we present a numerical observer for image quality assessment, aiming to predict human accuracy in a cardiac perfusion defect detection task for single-photon emission tomography (SPECT). In medical imaging, image quality should be assessed by evaluating the accuracy of a human observer for a specific diagnostic task. This approach is known as task-based assessment. Such evaluations are important for optimizing and testing imaging devices and algorithms. Unfortunately, human observer studies are costly and demanding on the time of expert readers. To address this problem, numerical observers have been developed as a surrogate for human readers to predict human diagnostic performance. The channelized Hotelling observer (CHO) with internal noise model has been found to predict human performance well in some situations, but does not always generalize well to unseen data. We have argued that finding a model to predict human observers should be also viewed as a machine learning problem. Following this approach, in this paper we propose a channelized relevance vector machine (CRVM) to predict human diagnostic scores in a detection task. We have previously used channelized support vector machines (CSVM) to predict human scores and have shown that this approach offers better and more robust predictions than the classical CHO method. The comparison of the proposed CRVM with our previously introduced CSVM method suggests that CRVM can achieve similar generalization accuracy, while dramatically reducing the model complexity and computation time.

7966-14, Session 3

Development of model observers applied to 3D breast tomosynthesis microcalcifications and masses

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The development of model observers for mimicking human detection strategies has followed from symmetric signals in simple noise to increasingly complex backgrounds. In this study we implement different model observers for the complex task of detecting a signal in a 3D image stack. The images sets are 29 slices of 400 by 400 pixels. The backgrounds come from real breast tomosynthesis acquisitions and the signal was simulated and reconstructed within the volume. Two different modes were employed, one for an 8 mm mass, and one for a cluster of microcalcifications, which are relevant to the early detection of breast cancer. The model observers were calculated using a channelized Hotelling observer (CHO) with dense difference-of-Gaussian channels, and a modified (Partial prewhitening [PPW]) observer which was adapted to realistic signals which are not circularly symmetric. The sustained temporal sensitivity function was used to filter the images template before applying the spatial templates. The only channel CHO calculated performed worse than the humans in a 4-AFC experiment. The other observers were PPW and outperformed human observers in every single case. The frame rate was fixed at 5 frames per second, which is a rate decided on after consulting with radiologists. This was a rather low speed and the temporal filtering did not affect the results compared to a data set with no human temporal effects taken into account. The study demonstrated that a model observer that can be used for both the detection of masses and the conceptually different detection of microcalcification clusters.

7966-15, Session 3

Numerical observer for cardiac motion assessment using machine learning

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In medical imaging, image quality is commonly assessed by measuring the performance of a human observer performing a specific diagnostic task. However, in practice, studies involving human observers are costly and difficult to implement. Therefore, numerical observers have been developed, aiming to predict human diagnostic performance to facilitate image quality assessment. In this paper, we present a numerical observer for assessment of cardiac motion in cardiac-gated SPECT images. Cardiac-gated SPECT is a nuclear medicine modality used routinely in the evaluation of coronary artery disease. Numerical observers have been developed for image quality assessment via detection of myocardial perfusion defects (e.g., the channelized Hotelling observer), but no numerical observer for cardiac motion assessment has been reported. Therefore, in this work, we present a method to design a numerical observer aiming to predict human performance in cardiac motion defects detection. Cardiac motion estimation is first performed using a deformable mesh model as reported in our earlier work on motion estimation. Motion features are then extracted from the estimated motion field and used to train a support vector machine predicting human scores (human observer confidence in the presence of the defect). Results show that the proposed method accurately predicts human scores and offers good generalization properties when tested on data with different level of post-reconstruction filtering.

7966-16, Session 3

Accounting for anatomical noise in SPECT with a visual-search human-model observer

H. C. Gifford, M. A. King, M. S. Smyczynski, Univ. of Massachusetts Medical School (United States)

Reliable human-model observers for detection studies in medical imaging are important for large-scale optimizations of imaging systems, but current model observers require frequent revalidation with human data. A visual-search (VS) observer framework for emission tomography may improve reliability by better simulating realistic localization-detection tasks. Under this framework, model observers execute a holistic search to identify tumor-like candidates and then perform careful analysis of these candidates. However, anatomical noise in the form of high radiotracer uptake in neighboring tissue can complicate the detection task. Some scanning model observers simulate the human ability to read around such noise by presubtracting a noise-free (NF) normal image from the test image, but this process can easily overstate human capabilities. We have evaluated methods of identifying anatomical noise for VS observers in a lesion detection task with simulated SPECT lung images. The study objective was to identify optimal iteration and postsmoothing parameters for SPECT reconstruction. Using the NF normal image with the VS observer overestimated human performances while predicting

a heavier optimal postsmoothing. A modified NF background estimate yielded a better estimate of the optimal postsmoothing for the humans. The objective is to develop a robust model for anatomical noise that can work without the NF data. Results from ongoing research along this line will be presented at the conference.

7966-17, Session 4

Support of the decision variable densities of the three-class ideal observer for bivariate trinormal data

D. C. Edwards, The Univ. of Chicago (United States)

Despite theoretical and practical difficulties, we are attempting to extend receiver operating characteristic (ROC) analysis to tasks with more than two classes. Previously we investigated a univariate trinormal model for the underlying data of a three-class ideal observer. Although analytically tractable, this is less realistic than a multivariate data model. We have developed expressions for the region of support of the decision variable probability density functions for bivariate trinormal underlying data, given certain constraints on the underlying data covariance matrices. We hope these results will aid in developing computational methods for evaluating observer performance under such a model.

7966-18, Session 4

Agreement between two versions of a CADx system: a simulation study

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A simulation study was conducted to investigate the agreement between current and updated versions of a CADx system. Performances of two versions of a CADx system are traditionally compared using metrics derived from the receiver operating characteristic (ROC) curve. These aggregate standalone performance measures may reveal the overall improvement of the CADx system due to the update, but do not provide information about the specific change in CADx output for individual cases. To address this issue, we used the concordance measure, which compares the ranks of scores for pairs of cases before and after the update of the system. This measure of agreement was investigated to assess the effect of three general areas for the system update: (1) enlargement of the training data set, (2) extraction and addition of new features into the feature pool, and (3) modification of the classifier structure. We separately studied the effect of the size of the original training set, the number of features, and the distribution and separation of the two classes in the feature space on the concordance and AUC measures. When the effect of an update was compared among datasets with differences in class separation, concordance was in general larger when the class separation was larger. The amount of change in AUC between the current and updated CADx system did not predict the degree of agreement between the two system versions. A large improvement in AUC could be accompanied with a larger or smaller agreement between the current and updated systems. Quantification of the degree of agreement between different versions of a standalone CADx system may serve to define a major algorithm update, and better depict the impact of that update.

7966-19, Session 4

Reader characteristics linked to detection of pulmonary nodules on radiographs: ROC vs JAFROC analyses of performance.

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The purpose of this study is to explore whether reader characteristics are linked to heightened levels of diagnostic performance in chest radiology using receiver operating characteristic (ROC) and jackknife free response ROC (JAFROC) methodologies. A set of 40 postero-anterior chest radiographs was developed, of which 20 were abnormal containing one or more simulated nodules, of varying subtlety. Images were independently reviewed by 12 board-certified radiologists including six chest specialists. The observer performance was measured in terms of ROC and JAFROC scores. For the ROC analysis, readers were asked to rate their degree of suspicion for the presence of nodules by using a confidence rating scale (1-6). JAFROC analysis required the readers to locate and rate as many suspicious areas as they wished using the same scale and resultant data were used to generate Az and FOM scores for ROC and JAFROC analyses respectively. Using Pearson methods, scores of performance were correlated with 7 reader characteristics recorded using a radIQ questionnaire. JAFROC analysis showed that improved reader performance was significantly ($p \leq 0.05$) linked with chest specialty ($p<0.03$), hours per week reading chest radiographs ($p<0.03$) and chest readings per year ($p<0.04$). ROC analyses demonstrated only one significant relationship, hours per week reading chest radiographs ($p<0.02$).The results of this study have shown that radiologist's performance in the detection of pulmonary nodules on radiographs is significantly linked to chest specialty, hours reading per week and number of radiographs read per year. Also, JAFROC is a more powerful predictor of performance as compared to ROC.

7966-20, Session 4

Estimating parameters of a model of visual search from ROC data: an alternate method for fitting proper ROC curves

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The binormal receiver operating characteristic (ROC) model often predicts an unphysical "hook" near the upper-right corner (1,1) of the ROC plot. There are several models for fitting proper ROC curves that avoid this problem. The purpose of this work was to describe another method that involves a model of visual search designed for modeling free-response data, and to compare the search-model predicted ROC curves with those predicted by PROPROC (proper ROC) software.

The search-model for FROC data is characterized by three parameters and cutoffs. An expression for the search-model ROC likelihood function was derived, maximizing which yielded estimates of the parameters and the fitted ROC curve. The highest rating method was used to infer ROC data from the FROC data. PROPROC analysis was performed using DBM-MRMC 2.0.

The method was applied to a dual-modality 5-reader FROC data set. The relative difference between the average AUCs for the two methods was less than 1%. A linear regression of the AUCs yielded an adjusted R-squared of 0.95 indicative of strong linear correlation. Although the shapes of the predicted ROC curves were different, the AUC's predicted by both methods were generally in good to excellent agreement. Unlike the ROC models, the search model also predicts location specific operating characteristic curves.

This study shows the feasibility of estimating parameters characterizing visual search from data acquired in a non-search paradigm. The resulting AUCs are in close agreement with those predicted by PROPROC.

7966-21, Session 4

Characterizing and optimizing rater performance for internet-based collaborative labeling

J. A. Stein, A. J. Asman, B. A. Landman, Vanderbilt Univ. (United States)

Labeling structures on medical images is crucial in determining clinically relevant correlations with morphometric and volumetric features. For the exploration of new structures and new imaging modalities, validated automated methods do not yet exist, and so researchers must rely on manually drawn landmarks. Voxel-by-voxel labeling can be extremely resource intensive, so large-scale studies are problematic. Recently, statistical approaches and software have been proposed to enable Internet-based collaborative labeling of medical images. While numerous labeling software tools have been created, the use of these packages as high-throughput labeling systems has yet to become entirely viable given training requirements. Herein, we explore two modifications to a typical mouse-based labeling system: (1) a platform independent overlay for recognition of mouse gestures and (2) an inexpensive touch-screen tracking device for non-mouse input. Through this study we characterize rater reliability in point, line, curve, and region placement. For the mouse input, we find a placement accuracy of 0.6±2.9 pixels (point), 0.3±3.6 pixels (curve), 0.16±0.94 pixels (line), and 0.76±0.4 (1 - Jaccard Index for region). The gesture software increased labeling speed by 33% overall and accuracy by 30-50% on point and line tracing tasks, but the touch screen module lead to slower and more error prone labeling on all tasks, likely due to relatively poor sensitivity. In summary, the mouse gesture integration layer runs as a seamless operating system overlay and could potentially benefit any labeling software; yet, the inexpensive touch screen system requires improved usability optimization and calibration before it can provide an efficient labeling system.

7966-22, Session 4

ROC analysis as a normative practice

X. He, Unaffiliated (United States)

Users of generalized ROC analysis often ask: there are so many figures-of-merit (FOMs) for the same task, which one should I use? A FOM represents its developer's belief on the mechanism of measuring task performance. Different researchers have different beliefs, resulting in different FOMs. These FOMs, unless monotonically related, do not rank task performance consistently. Yet task performance is an objective quantity, and is independent of the FOM used to measure it. This suggests that the objectivity of a FOM should be validated. I believe the confusions in generalized ROC are due to our incomplete understanding of binary ROC. In this work, I introduce two concepts: measurement and rationality. These concepts are extremely important in ROC research, but have almost completely escaped our attention. Based on these concepts, I provide a new understanding of ROC analysis by justifying ROC curve and AUC value as a valid measurement for performance using the two benchmarks: representation and uniqueness. I will also present the potentials of the new understanding: 1) the equivalence between an ideal observer and a human observer in a clinical reader study will be revealed; 2) the solution to a three-class ROC analysis for a human observer is straightforward, and specific steps toward the solution will be provided, and 3) almost every aspect in current binary reader studies can be improved to better estimate the true performance.

7966-23, Session 5

The observer end of digital imaging: integrating the digital microscope into clinical practice

S. M. Hewitt, National Institutes of Health (United States)

The development of digital microscopy, and enablement of whole-slide digital imaging alters the fundamental relationship of the observer from the microscope slide. Nowhere else is this shift more significant than anatomic pathology. Over a century of anatomic pathology has been based on the microscopic examination of tissue for cyto- and morphologic features by means of a microscope. Although the microscope has evolved substantially over the last century, evaluation of a microscopic image projected on a computer display differs substantially from direct observation by means of an optical microscope. The challenge is to define how this difference in approach affects diagnostic histopathology and provide approaches, guidelines and refinements to improve patient care.

7966-43, Poster Session

Assessment of a CAD scheme in selecting the optimal focused microscopic scanning images of the metaphase chromosomes

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Visually searching for analyzable metaphase chromosome cells under microscopes is a routine and time-consuming task in genetic laboratories to diagnose cancer and genetic disorders. To improve detection efficiency, consistency, and accuracy, we developed an automated microscopic image scanning system using 100X oil immersion objective lens to acquire images that has sufficient spatial resolution allowing clinicians to do diagnosis. Due to the high-resolution, the field of image depth is very limited and multiple scans up to seven layers are required. Thus, a metaphase cell can have multiple images at different focal levels. Among them only one or two are adequate for the diagnosis and the others are fuzzy images. In this study, we developed and tested a computer-aided detection (CAD) scheme to automatically select one image with the sharpest image quality and discard all of the other fuzzy images based on the computed sharpness index. From three scanned bone marrow specimen slides, 100 chromosome cells with 534 images were selected to build a testing dataset. For each cell, the CAD scheme selects one image with the maximum sharpness index. Three observers also independently visually selected one best image for diagnosis from each cell. The agreement rate between CAD and visually selected images ranges from 89% to 96%, which is also very comparable to the agreement rate between the two observers. This experiment demonstrated the feasibility of applying a CAD scheme to select the images with sharpest high-resolution metaphase chromosome cell and potentially improve diagnostic efficiency and accuracy in the future clinical practice.

7966-45, Poster Session

Quantitative evaluation of six graph based semi-automatic liver tumor segmentation techniques using multiple sets of reference segmentation

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Graph based semi-automatic tumor segmentation techniques have demonstrated great potential in efficiently measuring tumor size from CT images. Comprehensive and quantitative validation is essential to ensure the efficacy of graph based tumor segmentation techniques in clinical applications. In this paper, we present a quantitative validation study of six graph based 3D semi-automatic tumor segmentation techniques using multiple sets of expert segmentation. The six segmentation techniques are Random Walk (RW), Watershed based Random Walk (WRW), LazySnapping (LS), GraphCut (GHC), GrabCut (GBC), and GrowCut (GWC) algorithms. The validation was conducted using clinical CT data of 29 liver tumors and four sets of expert segmentation. The performance of the six algorithms was evaluated using accuracy and reproducibility. The accuracy was quantified using Normalized Probabilistic Rand Index (NPRI), which takes into account of the variation of multiple expert segmentations. The reproducibility was evaluated by the change of the NPRI from 10 different sets of user initializations. Our results from the accuracy test demonstrated that RW (0.63) showed

the highest NPRI value, compared to WRW (0.61), GWC (0.60), GHC (0.58), LS (0.57), GBC (0.27). The results from the reproducibility test indicated that GBC is more sensitive to user initialization than the other five algorithms. Compared to previous tumor segmentation validation studies using one set of reference segmentation, our evaluation methods use multiple sets of expert segmentation to address the inter or intra rater variability issue in ground truth annotation, and provide quantitative assessment for comparing different segmentation algorithms.

7966-46, Poster Session

Applying resonance-frequency based electrical impedance spectroscopy to assess the risk of developing thyroid cancer

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Incidence of thyroid cancer is rising faster than other malignancies and has nearly doubled in the US in the last 30 years. Because a large fraction of the population is likely to have detectable thyroid nodules but the vast majority (>95%) are benign, accurate detection and diagnosis of thyroid cancer present a diagnostic dilemma in the clinical practice. Although ultrasound guided Fine Needle Aspiration Biopsy (FNAB) is excellent for triaging patients, up to 25% of FNABs are inconclusive. As a result, definitive diagnosis requires “an exploratory surgery” and as many as 50,000 are performed in the US annually. It would be extremely beneficial if we could develop a non-invasive procedure that could reliably predict the likelihood of malignancy of otherwise indeterminate thyroid nodules thereby reducing the number of these “exploratory” thyroidectomies performed under general anesthesia. Electrical Impedance Spectroscopy (EIS) was considered as a possible approach to address this problem. However, the diagnostic accuracy of EIS is too low for routine clinical use. In our group, we developed a substantially modified technology termed Resonance-frequency based Electrical Impedance Spectroscopy (REIS). Based on the encouraging initial results in detecting and classifying breast abnormalities, we applied REIS to detect and evaluate the thyroid nodules aiming to substantially improve diagnosis of indeterminate thyroid nodules. In this study we presented a new multi-probe based REIS device specifically designed for the assessment of indeterminate thyroid nodules. Our initial assessment demonstrated the feasibility of applying the proposed REIS device and measurement approach in a very busy clinical setting. The measured resonance frequency difference between the malignant and benign nodules also makes it possible to more accurately classify indeterminate thyroid nodules.

7966-47, Poster Session

Evaluation of agreement in corneal thickness measurements obtained using optical coherence tomography and ultrasound technique and determination of its specificity in keratoconus screening

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The aims of the present study are 1) to evaluate inter and intra observer repeatability of OCT corneal thickness measurements 2) to investigate the agreement in corneal thickness obtained using an ultrasound pachymeter and the non contact high resolution optical coherence tomographer (OCT) 3) to evaluate the false positive rate of identifying keratoconic suspects on the basis of standard machine protocol. Measurements were performed on 51 eyes of 51 individuals without any known corneal pathology. Altman and Bland plots were analyzed to determine agreement of corneal thickness measurements obtained using OCT and ultrasound pachymeter; linear regression analysis was performed to evaluate its interchangeability. The agreement between the OCT and ultrasonic pachymeter measurements was best for the central corneal thickness with a mean bias of 13.4 microns, with OCT values being lower than the ultrasound pachymeter. The agreement of measurements in the mid-peripheral cornea was poor, with bias in measurements ranging from 33 to 55 microns. The OCT measurements were repeatable with no differences in values between intra and inter observer repeat measurements. Using standard machine protocol for keratoconus screening, utilizing 1 of 4 criteria gave a specificity of 86% and using 2 of 4 criteria gave a specificity of 98%.

7966-48, Poster Session

Fusion of classifiers for REIS-based detection of suspicious breast lesions

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After developing and installing a multi-probe resonance-frequency electrical impedance spectroscopy (REIS) system aiming to detect breast abnormalities that might indicate a developing breast cancer, we have been conducting a large prospective clinical study to explore the feasibility and performance of applying this REIS system to classify younger women (< 50 years old) into two groups of higher and lower risk of having or developing breast cancer. The system comprises one central probe that touches with the nipple, and six side probes uniformly distributed along the outside circle and contact with six points on the outer breast skin surface. In this preliminary study, we randomly selected a subset of 174 examination cases that have completed both REIS examinations and diagnostic (or follow-up) verification. Among these, 66 examinations were recommended for biopsy due to detection of a highly suspicious breast lesion (“positives”), and 108 were determined negative during mammography screening (“negatives”). A set of REIS-based features, extracted using a mirror-matched manner, was computed and fed into five machine learning classifiers. A genetic algorithm was used to select an optimal subset of features for each of the five classifiers. Three fusion rules, namely sum rule, weighted sum rule and weighted median rule, were used to combine the results of the classifiers. Performance evaluation was performed using a leave-one-case-out cross-validation method. The results indicated that REIS provides a new promising technology to identify younger women with higher risk of having or developing breast cancer. Furthermore, it was shown that fusion rule, such as weighted median fusion rule and weighted sum fusion rule may significantly improve performance as compared with the best single classifier.

7966-49, Poster Session

A software tool to compare contrast-detail detection in uniform and in real mammographic backgrounds

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A software tool is presented to merge CDMAM phantom images with real mammographic backgrounds. It allows to compare human or model observers’ performance in contrast-detail detection using uniform or mammographic backgrounds.

It is very well known that the human performance in contrast-detail detection in mammographic backgrounds is much lower that which can be achieved in white noise (flat) backgrounds, such as a CDMAM phantom produces. That performance cannot be inferred from the data acquired in flat backgrounds due to the local characteristics of the structures in mammographic backgrounds.

It is of interest to compare the response of a mammography system to the same set of signals, either embedded in flat or in real backgrounds.

This comparison achieves two goals. One is to analyze the variation of the recognition threshold of the system for both backgrounds. The other goal is to analyze the performance of a human observer or a model observer over the same set of signals, varying the nature of the backgrounds.

The software tool presented here automatically locates the grid crossing points of a CDMAM image. In a second image which shows a real mammography, the user can select a zone of interest that will be merged with the original CDMAM image cell by cell. In this work a set of measurements of 8 CDMAM images has been analyzed. We can preview the variation of the contrast-detail detection for a human observer and a perceptual metric(R*).

7966-50, Poster Session

Comparison of the detection rates in reduced image by difference of interpolation method

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In the soft copy diagnosis, each pixel of the detector is displayed to the correspondent pixel of liquid crystal display (LCD). But when the image is displayed at the first time, the entire image may be reduced. We examined the influence that the difference of image reduction rate on LCD exerts on detection performance by using observer performance experiment. Moreover, to find the best interpolation method, we investigated the several interpolation methods. We made a simulation image which is similar to Burger phantom. This image consists of 288 signals, each of a different size and contrast. The matrix size is the same as Phase Contrast Mammography (PCM). We gradated the simulation image by using an MTF of a geometric blur, and the image was added to the noise image which is uniformly exposed with PCM. Then the image was reduced by using the nearest-neighbor, the bilinear, and the bicubic methods. The reduction rates were calculated as the ratios of the number of pixels of LCDs to those of PCM. We displayed the reduced images on LCD and examined the detection performance. Results of physical evaluation examined before showed that sharpness and granularity have worsened both in proportion to the reduction rate. The detection performance deteriorated as the reduction rate becomes high. In the comparison of the interpolation methods, the detection performance of the nearest-neighbor method was worse than those of other interpolation methods. The bilinear method is the most suitable for the reduction of the image.

7966-51, Poster Session

FBP and NBC: a comparison of lesion detection performance in head CT imaging

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Detecting low contrast lesions in head CT is a challenging task, and it is generally assumed that improved contrast can lead to improved performance. Recently, a modified image reconstruction algorithm has been introduced by a commercial vendor to address this issue. This new reconstruction, called neuro-best-contrast (NBC) is a modified version of the standard filtered back projection (FBP) reconstruction technique. NBC enhances image contrast, allowing for a better differentiation between low contrast lesions and background. The purpose of this study was to compare the detection performance for small lesions in head CT images reconstructed using NBC and FBP.

Head CT images were reconstructed using both, FBP and NBC. In each case, the images were modified (post reconstruction) to include artificial lesions of 3 mm, 7 mm and 10 mm. Four observers (two medical students, two medical physicists) were used to perform Alternate Forced Choice (2-AFC) experiments that measured the lesion contrast (I92%) corresponding to a detection accuracy of 92%. The results plotted as log(I92%) versus log(lesion size), for the two techniques. A comparison of the I92% values allowed us to compare the relative efficacy of the two techniques in terms of their ability to detect small lesions.

The I92% data for the two techniques do not show a significant difference for the 3 and 7 mm lesion sizes. The I92% values for the 10 mm lesion show a relatively large inter-observer variation.2-AFC methodology does not indicate a clear advantage of NBC over FBP in terms of detection performance for lesions less than 10 mm.

7966-52, Poster Session

The effects of anatomical information and observer expertise on abnormality detection task

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In this paper is presented a pioneering study on the influences of the anatomical information of MR images and observer expertise on the abnormality detection task.

MRI is exquisitely sensitive for detecting brain abnormalities, particularly in the evaluation of white matter diseases, e.g. multiple sclerosis (MS). For that reason, MS lesion is simulated as the target stimuli for the detection. Different backgrounds are used in the two experiments: homogeneous region of white matter tissue in the first experiment; one slice of a healthy brain MR image in the second experiment. One expert (more than 10 years' experience), three radiologists (less than 5 years' experience) and eight naïve observers (without any medical education background) have performed these experiments, during which they have been asked different questions: the three radiologists and eight naïve observers were asked if they saw any hyper-signal which stands for a MS lesion, while the expert was asked if he saw any clinically significant sign. With the percentages of response "yes" displayed on the y-axis and the lesion intensity contrasts on the x-axis, psychometric function is generated from the observer' responses.

The analysis of the psychometric functions and the calculated thresholds indicate that radiologists have better hyper-signal detection ability than naïves, which is intuitively shown by the lower simple visibility thresholds of radiologists. But when the radiologists perform a higher level of task - to detect a clinically significant sign, their detection thresholds are elevated. Moreover, the study indicates that for the radiologists, the simple visibility thresholds remain the same with and without the anatomical information, which however yields a reduction of the thresholds for the clinically significant sign detection task.

7966-53, Poster Session

Application of artificial neural network in simulating subjective evaluation of tumor segmentation

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Systematic validation of tumor segmentation technique is very important in ensuring the accuracy and reproducibility of tumor segmentation algorithm in clinical applications. In this paper, we present a new method for evaluating 3D tumor segmentation using Artificial Neural Network (ANN) and combined objective metrics. In our evaluation method, a three-layer feed-forwarding backpropagation ANN is first trained to simulate radiologist's subjective rating using a set of objective metrics. The trained neural network is then used to evaluate the tumor segmentation on a five-point scale in a way similar to expert's evaluation. The accuracy of segmentation evaluation is quantified using average correct rank and frequency of the reference rating in the top ranks of simulated score list. Experimental results from 93 lesions showed that our evaluation method performs better than individual metrics. The optimal

combination of metrics from normalized volume difference, volume overlap, Root-Mean-Square symmetric surface distance and maximum symmetric surface distance showed the smallest average correct rank (1.43) and highest frequency of the reference rating in the top two places of simulated rating list (93.55%). Our results also demonstrate that the ANN based non-linear combination method showed better evaluation accuracy than linear combination method in all performance measures. Our evaluation technique has the potential to facilitate large scale segmentation validation study by predicting radiologist's rating, and to assist development of new tumor segmentation algorithms. It can also be extended to validation of segmentation algorithms for other applications.

7966-54, Poster Session

Optimisation of hepatic lesion detection with computed tomography (CT): Is randomisation of lesion location necessary?

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Sophisticated techniques to randomize the location of abnormalities are often employed for CT dose optimization. This phantom-based study compares observer performance for the detection of randomly-positioned hepatic lesions to that of location-fixed lesions to determine if randomization of lesion placement is necessary for dose optimization. A phantom containing fixed lesions (diameter 2.4mm, 4.8mm and 9.5mm) was scanned at various exposure and slice thickness settings. A second image set was created by electronically cutting lesions from the phantom images and pasting them into background-only images. Nine observers, blinded to lesion location in the second image set, reviewed all images under standardized viewing conditions. Visualization of lesions was scored using a four-point scale. Observer scores for the two methods were correlated for all lesions, and for each lesion size using Spearman's rank correlation coefficient (r). There was very high correlation between the observer scores for all lesions ($r=0.94$, $p<0.01$) and for the 9.5mm lesion ($r=0.94$, $p<0.01$). There was moderate correlation for the 4.8mm and 2.4mm lesions ($r=0.509$, $p<0.09$, $r=0.64$, $p<0.02$). When considering all lesions, or the 9.5mm lesion independently, randomization did not alter observer scores, suggesting random location of large lesions is unnecessary for dose optimization. For the smaller lesion sizes correlation between the two methods is less robust, with observer scores generally higher for fixed lesion location. Conclusion: If lesion size is large or unimportant, dose optimization can be performed using a phantom with fixed lesions. For small lesions, randomized lesion location may be warranted, thus having implications for phantom design.

7966-55, Poster Session

Impact of hybrid SPECT/CT imaging on the detection of single parathyroid adenoma

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OBJECTIVE: The aim of this investigation is to determine the impact of hybrid single photon emission computed tomography/computed tomography (SPECT/CT) on the detection of parathyroid adenoma.

MATERIALS AND METHODS: 16 patients presented with suspected parathyroid adenoma localised within the neck. All patients were injected with Tc-99m sestamibi and were scanned with a GE Infinia Hawkeye SPECT/CT. There were seven negative and nine positive confirmed cases. Five expert radiologists specializing in nuclear medicine were asked to report on the 16 planar and SPECT data sets and were then asked to report on the same randomly ordered data sets with the addition of CT. Receiver operating characteristic (ROC) analysis was performed using the Dorfman-Berbaum-Metz multireader-multicase methodology and sensitivity and specificity values were generated. A significance level of $p < 0.05$ was set for all comparisons.

RESULTS: Analysis demonstrated the area under the ROC curve of 0.62 and 0.69 for SPECT and SPECT/CT respectively ($p = 0.29$). Mean sensitivity scores increased from 0.60 to 0.78 ($p = 0.17$) and specificity scores decreased from 0.46 to 0.34 ($p = 0.25$) with the addition of the CT data.

CONCLUSION: This preliminary investigation suggests that extra CT information may increase lesion detection as well as false positive rates for SPECT-based investigations of a single parathyroid adenoma. However the difference in diagnostic efficacy between the two groups was not found to be statistically significant therefore requiring further investigation with additional observers. These findings have implications beyond the clinical situation described here.

7966-56, Poster Session

Role of expertise and contralateral symmetry in the diagnosis of pneumoconiosis: an experimental study

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Objectives: To study the effects of using contralateral symmetric (CS) information present in chest radiographs in the diagnosis of pneumoconiosis1. The role of expertise and the influence of CS information on the performance of readers with different expertise level are also of interest.

Methods: Experimental subjects ranging from novices & medical students to staff radiologists were presented with 17 double and 16 single lung images, and were asked to give profusion ratings for each lung zone. Eye movements and the time for their diagnosis were also recorded.

Results: Kruskal-Wallis test ($\chi^2(6) = 13.38$, $p = .038$), showed that the observer error (average sum of absolute differences) in double lung images differed significantly across the different expertise categories when considering all the participants. Wilcoxon-signed rank test indicated that the observer error (Mdn = 0.813) was significantly higher for single-lung images ($Z = 3.13$, $p < .001$) than for the double-lung images (Mdn = 0.620) for all the participants. Mann-Whitney test ($U = 28$, $p = .038$) showed that the differential error between single and double lung images is significantly higher in doctors [staff & residents] (Mdn = 0.38) than in non-doctors [others] (Mdn = 0.38).

Conclusion: Expertise & CS information plays a significant role in the diagnosis of pneumoconiosis. CS information helps in diagnosing pneumoconiosis by reducing the general tendency of giving less profusion ratings. Training and experience appear to play important roles in learning to use the CS information present in the chest radiographs.

7966-57, Poster Session

Analysis of ARIOL's imaging conditions: contrast, brightness and resolution

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ARIOL'S serials instruments have been widely used diagnostic use for many years. It is intended for in vitro diagnostic use as an aid to the pathologist in the detection, classification and counting of cells of interest based on particular color, intensity, size, pattern and shape. Many techniques were developed in order to intensify their applications in area such as ER/PR (progesterone receptors). These techniques had a strong

link with imaging conditions. This paper suggested Rose' law could be used in the analyzing and evaluating imaging conditions of ARIOL's instrument. Imaging samples and data are discussed based on Rose's law. Especially the analysis results could be constructive to calibration of instruments.

7966-58, Poster Session

Analysis of the number of distinct findings obtained by multiple readers in an MRMC study: When do findings obtained from the addition of new readers become redundant, or otherwise negligible?

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The goals of our study were 1) to investigate the relationship between the number of radiologists' reading a dataset of thoracic computed tomography (CT) images to identify lung nodules and the number of distinct findings and 2) to determine the number of readers needed to identify almost all clinically distinct findings on a dataset. It is envisioned that such determination could serve as a benchmark for CAD system assessment. To answer this question, we used data from a multi-reader multi-case (MRMC) observer study that consisted of six radiologists interpreting 85 thoracic CT examinations. For each possible reader grouping, the number of distinct findings identified by the readers in the group was calculated. Five types of regression models used to describe the relationship between the average number of distinct findings per case and the number of readers needed were compared. The result showed that the logistic model best fitted the data and our assumption that adding more readers after a certain reader set size would only add redundant findings and, therefore, would be negligible. Using this model, the predicted number of readers was found to depend on the type of findings considered. Our study showed that the number of clinically distinct findings that can be identified by radiologists on CT lung examinations without the use of a CAD system may be limited and that identifying almost all of these findings may only require a limited number of readers.

7966-59, Poster Session

Analysis of the correlation between the ROIs of transrectal near infrared and transrectal ultrasound images of the prostate cancer using an observer model-based approach

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A novel dual-modality prostate-imaging method, trans-rectal ultrasound-coupled near-infrared (NIR) optical tomography (TRUST), has been developed to improve the image-guidance for prostate biopsy by using both anatomic details from trans-rectal ultrasonography (TRUS) and optical functional information rendered by TRUS-coupled NIR tomography. Trans-rectal NIR tomography has the potential of effectively characterizing the malignancy of lesions suspicious on TRUS and detecting lesions that are inconspicuous on TRUS. In this study, we investigated the utility of human observer models for predicting the correlation of ROIs in NIR and TRUS, for the lesions that were suspicious initially on NIR only but became visible on US as well at advanced stage. Specifically, the correlating patterns between concurrent US and NIR images of longitudinal changes of prostate cancer developed as a model in canine prostate were investigated. The US images were pre-processed to suppress speckle noise and enhance the appearance of conspicuous lesions. A visual discrimination model was then applied to quantify the visual differences at different stages of cancer development for extracting location and shape information. Finally, a channelized Hotelling observer model was used to detect suspicious patterns in US images and results were compared to the NIR images wherein the lesions are significantly more conspicuous. Experimental results on the available image datasets indicate that a correlation between NIR and US image patterns of prostatic tumor development can be established and the detection accuracy is expected to be improved when more image datasets can be tested. Further validation is feasible by a carefully designed phantom study.

7966-60, Poster Session

Reproducibility of an imaging based prostate cancer prognostic assay

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The Prostate Px+ prognostic assay offered by Aureon Biosciences is designed to predict progression post primary treatment for prostate cancer patients based on their diagnostic biopsy specimen. The assay is driven by the automated image analysis of biological specimens. Three different histological sections are analyzed for morphometric as well as immunofluorescence protein expression properties within areas of tumor digitally masked by expert pathologists.

The assay was developed on a multi-institution cohort of up to 9 images from each of 1027 patients. The variation in histological sections, staining, pathologist tumor masking and the region of image acquisition all have the potential to significantly impact imaging features and consequently the reproducibility of the assay's results for the same patient. This study analyzed the reproducibility of the assay in 50 patients who were re-processed within 3 months in a blinded fashion as de-novo patients.

The key assay results reported were in agreement in 94% of the cases. The two independent endpoints of risk classification reproduced results in 90% and 92% of the predictions. This work presents one of the first assessments of the reproducibility of a commercial assay's results given the inherent variations in images and quantitative imaging characteristics in a commercial setting.

7966-61, Poster Session

Assessment of updated CAD without a new reader study: effect of calibration of computer output on the computer-aided reader performance in CADx

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It is very resource-demanding to assess each new version of a CAD system through a new reader study. We conjecture that the aided reader performance on a new version can be predicted by using certain characteristics of the computer output and the reader study conducted when the CAD system was initially introduced. This would likely reduce the need for additional reader studies. However, investigations are needed to develop a sound scientific foundation for this conjecture. In this work, we consider a CADx system that outputs a disease score to aid the physician in making a diagnostic decision on a located lesion. Our major contribution is to show that calibration may be a characteristic of a computer output that should be accounted for to achieve the goal stated in the conjecture. We used a bivariate bi-beta distribution to simulate both the disease scores produced by the CAD in its base-line version and by the reader alone. We then applied a monotonic transformation to the computer output to simulate the computer output in a new version, i.e., the scores in the two versions differ only in calibration. By assuming certain mechanisms for combining the computer output and the reader-

alone scores, we were able to compute the aided reader performance in terms of AUC. Our results show that the aided reader performance may change substantially as calibration changes. We conclude that rank-based measures alone may not be sufficient, and calibration may be important additional information, to characterize the computer output in order to predict the aided reader performance in new versions of CADx.

7966-62, Poster Session

Streak artefact quantification for abdominal CT

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Streaking artefacts in computed tomography (CT) can be caused by photon starvation which itself can occur in highly attenuating regions. Patient positioning can influence the attenuation e.g. by arms raised or down in an abdominal CT scan.

However, positioning the arms alongside the body increases attenuation, streaking artefacts causing a decrease in image quality can be expected.

Measuring the quality decrease is the purpose of this article.

We implemented several different automatic quantification methods based on high pass filtering and noise measurement and compared their output to the judgement of two radiologists.

Our first streak detection filter is a simple line detection (high pass) filter, the other filter looked more like a localised Radon transform, i.e. was simply adding up several points on a line of a distinct angle. Both filter were used for several different angles.

Abdominal CT volumes of 80 intensive care patients were selected retrospectively. Half of them had both their hands up, the others had their hands alongside the body. A region of interest (ROI) was chosen by a radiologist. A questionnaire was designed to enable the radiologists to assess artefacts.

Wilcoxon rank tests showed highly significant differences between the two subsets (arms up and down) for all tested methods and also for the rating of the radiologists. High correlation of the filter ratings with the radiologists was found.

Total variation turned out to be not the best measure.

The correlation from measurements and clinical usability enables to predict the usability by image processing.

7966-63, Poster Session

High luminance monochrome vs color displays: impact on performance and search

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To determine if diagnostic accuracy and visual search efficiency with a high luminance (400 cd/m2) medical-grade color display are equivalent to a high luminance (400 cd/m2) medical-grade monochrome display. Six radiologists viewed 50 chest images, half with a pulmonary nodule and half without. They viewed the images once on a medical-grade 3-Mpixel color LCD display and once on a medical-grade 3-Mpixel monochrome LCD display from the same manufacturer. Both displays had a pixel pitch of 0.21 mm, were set to the same maximum (400 cd/m2) and minimum (0.75 cd/m2) luminance levels, similar white points, and calibrated to DICOM GSDF. Observers reported whether or not a nodule was present and their confidence. Total viewing time was recorded. On 15 cases eye-position was recorded. Confidence data were analyzed using Multi-Reader Multi-Case ROC. There was no statistically significant difference (F = 0.0136, p = 0.9078) between color (mean Az = 0.8981, se = 0.0065) and monochrome (mean Az = 0.8945, se = 0.0148) diagnostic performance. Total viewing time per image did not differ significantly (F = 0.392, p = 0.5315) as a function of color (mean = 27.36 sec, sd = 12.95) vs monochrome (mean = 28.04, sd = 14.36) display. There were no significant differences in decision dwell times (true and false, positive and negative) for color vs monochrome displays. At least for the task of detecting nodules in chest images, diagnostic accuracy and visual search efficiency (viewing time) are equivalent when using 3-Mpixel medical-grade color and monochrome LCD displays.

7966-64, Poster Session

Study of signal-to-noise ratios considered human visual characteristics

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The effects of imaging parameters on detectability haven't been clear. So, we investigated the availability of signal-to-noise ratios (SNR) considered human visual characteristics, such as the visual spatial frequency response and internal noise.

We calculated the amplitude model (SNRa) and the internal noise model (SNRi). We studied the relationship between these SNR and visual image quality for the task of detecting the signal. We thought some imaging cases; several diameter of the signal, contrast, and reduction size of the image. These SNR were calculated by measuring signal's spatial frequency characteristics, modulation transfer function (MTF) of the system, the displayed MTF and noise power spectrum (NPS) of the system. The value of human visual characteristics was decided from previous studies. In the perceptual evaluation, the signal detection rate was defined as the number of detection divided by the number of signals.

MTF of the system was improved and the NPS value was decreased by reducing size of the image. The SNRa value, the SNRi value and the signal detection rate were decreased by reducing the diameter of the object, the contrast, and the size of image. But, there was no distinction between the SNRa and the SNRi. This is because nyquist frequency of the displayed MTF is 3cycles/mm, we had to calculate these SNR in this frequency range. So, high spatial frequency range was not reflected in calculations of these SNR. Moreover, because the contrast of the signal used in this study was high, effect of the internal noise was small.

7966-65, Poster Session

Radiation dose reduction in digital radiography using wavelet-based image processing methods

H. Watanabe, D. Tsai, Y. Lee, E. Matsuyama, Niigata Univ. (Japan); K. Kojima, Hamamatsu Univ. (Japan)

In the clinical implementation of digital radiography, it is imperative to use an appropriate level of radiation for the diagnostic task. It is known that a trade-off exists between noise level and radiation dose. On one hand, a higher radiation dose will lower the noise level but may impart unnecessarily high radiation doses to the patient. On the other hand, a lower radiation dose will lower the signal-to-noise ratio of the image and consequently negatively affect the presentation of image information. Thus, it is important to obtain radiological images that provide more diagnostic information at a lower radiation dose. In order to resolve these problems, several investigations have reported that wavelet-based image processing techniques are effective in reduction of radiation dose. In this paper, we propose a denoising method using wavelet transform combined with an algorithm that employs sigmoid function to weight the wavelet coefficients. To verify the effectiveness of the proposed method, the modulation transfer function (MTF), noise power spectrum (NPS), contrast-to-noise ratio, and peak signal-to-noise ratio of the processed computed radiography (CR) images were measured for comparison. Furthermore, visual evaluation was also performed. Experimental results showed that sigmoid-type transfer curves for wavelet coefficient weighting adjustment could improve the MTF while maintaining the NPS

level within an acceptable limit. Our visual evaluation showed that an approximately 40% reduction in exposure dose might be achieved with the proposed method in hip joint radiography.

7966-23, Keynote

The observer end of digital imaging: integrating the digital microscope into clinical practice

Stephen M. Hewitt, National Institutes of Health (United States)

The development of digital microscopy, and enablement of whole-slide digital imaging alters the fundamental relationship of the observer from the microscope slide. Nowhere else is this shift more significant than anatomic pathology. Over a century of anatomic pathology has been based on the microscopic examination of tissue for cyto- and morphologic features by means of a microscope. Although the microscope has evolved substantially over the last century, evaluation of a microscopic image projected on a computer display differs substantially from direct observation by means of an optical microscope. The challenge is to define how this difference in approach affects diagnostic histopathology and provide approaches, guidelines and refinements to improve patient care.

7966-24, Session 5

Changes in visual search patterns of pathology residents as they gain experience

E. A. Krupinski, R. S. Weinstein, The Univ. of Arizona (United States)

The goal of this study was to examine and characterize changes in the ways that pathology residents examine digital or “virtual” slides as they gain more experience. A series of 20 digitized breast biopsy virtual slides (half benign and half malignant) were shown to 6 pathology residents at three points in time - at the beginning of their first year of residency, at the beginning of the second year, and at the beginning of the third year. Their task was to examine each image and select three areas that they would most want to zoom on in order to view the diagnostic detail at higher resolution. Eye position was recorded as they scanned each image. The data indicate that with each successive year of experience, the residents’ search patterns do change. Overall it takes significantly less time to view an individual slide and decide where to zoom, significantly fewer fixations are generated overall, and there is less examination of non-diagnostic areas. Essentially, the residents’ search becomes much more efficient and after only one year closely resembles that of an expert pathologist. These findings are similar to those in radiology, and support the theory that an important aspect of the development of expertise is improved pattern recognition (taking in more information during the initial Gestalt or gist view) as well as improved allocation of attention and visual processing resources.

7966-25, Session 5

Characterizing virtual slide exploration through use of ‘search maps’

C. R. Mello-Thoms, Univ. of Pittsburgh Cancer Institute (United States); C. A. Mello, Univ. Federal de Pernambuco (Brazil); O. Medvedeva, E. Tseytlin, R. Crowley, Univ. of Pittsburgh (United States)

For certain skin diseases, such as melanocytic and squamoproliferative lesions, clinical guidelines are in place which require these cases to be diagnosed by a dermatopathologist; on the other hand, for inflammatory skin diseases, no such requirements exist, and general pathologists read and diagnose these cases, even though these pathologists did not have any specialized training in Dermatopathology. This yields a lot of error and disagreement. Furthermore, very little is known about the process by which pathologists arrive at a diagnosis on a case. This process is an integration of the pathologist’s slide exploration strategy, perceptual information gathering and cognitive decision making. We have developed a methodology to statically represent the pathologists’ visual search of digital slides by creating ‘search maps’. In these maps slide exploration is divided into three parts, according to the magnification range used. Thus, areas explored at low magnification (<4x), medium magnification (>4x-10x) and high magnification (>10x-20x) are represented separately. Moreover, representation using the ‘search maps’ allows for quantitative analysis and comparison of slide exploration strategy. In this paper we have compared the search maps of experienced pathologists (including a dermatopathologist) and of pathology residents ‘before’ and ‘after’ their Dermatopathology rotation. Our goal was to understand how search differs between the experts and the trainees.

7966-26, Session 6

Validation of a new digital breast tomosynthesis medical display

C. Marchessoux, Barco N.V. (Belgium); N. Vivien, Univ. de Poitiers (France); A. Kumcu, T. R. Kimpe, Barco N.V. (Belgium)

The main objective of this study is to evaluate and validate the new Barco medical display MDMG-5221 which has been optimized for the Digital Breast Tomosynthesis (DBT) imaging modality system, and to prove the benefit of the new DBT display in terms of image quality and clinical performance. The clinical performances are evaluated by the detection of micro-calcifications inserted in reconstructed Digital Breast Tomosynthesis slices. The slices are shown in dynamic cine loops, at two frames rates. The statistical analysis chosen for this study is the Receiver Operating Characteristic Multiple-Reader, Multiple-Case methodology, in order to measure the clinical performance of the two displays. Four experienced radiologists are involved in this study. For this clinical study, 50 normal and 50 abnormal independent cases were used. The result is that the new display outperforms the mammography display for a signal detection task using real DBT images viewed at 25 and 50 slices per second for a signal detection task using real DBT images viewed at 25 and 50 slices per second. In the case of 50 slices per second, the p-value = 0.0664. For a cut-off where alpha=0.05, the conclusion is that the null hypothesis cannot be rejected, however the trend is that the new display performs 6% better than the old display in terms of AUC. At 25 slices per second, the difference between the two displays is very apparent. The new display outperforms the mammography display by 10% in terms of AUC, with a good statistical significance of p=0.0415.

7966-27, Session 6

Is image manipulation necessary to interpret digital mammographic images efficiently?

Y. Chen, A. G. Gale, Loughborough Univ. (United Kingdom); J. H. James, Nottingham City Hospital (United Kingdom); A. Turnbull, Royal Derby Hospital (United Kingdom)

With the introduction of digital breast screening across the UK, screeners need to learn how best to inspect these images. A key advantage over mammographic film is the facility to use workstation image manipulation tools. Forty two-view FFDM screening cases, representing malignant, normal and benign appearances were examined by fourteen radiologists and advanced practitioners from two UK screening centres. For half the cases, the mammography workstation image manipulation tools could be employed and for the other half these were not used. Participants classified each case and indicated whether an abnormality was present. Throughout the study the participants’ visual search behaviour as well as their image manipulations were recorded. Whether or not image

manipulation tools were used made very little difference to overall performance (t-test, p>.05) as confirmed by JAFROC analysis Figure-Of-Merit values of 0.816 and 0.838 (with and without tools respectively); performance not using tools was better. However, using tools significantly increased inspection time (p<0.5) as well as participants' confidence. Detailed examination of participants' image inspection behaviour elicited that when imaging tools were used then they spent 17-77% of their time manipulating the images; with the less experienced participants spending more time using such tools. Eye movement data demonstrated that when abnormalities were missed then this was typically due to visual search errors. For these cases, whilst using imaging tools was not necessary to identify abnormalities, their use improved confidence, especially in identifying normal appearances. With experience, less use of such tools was evident.

7966-28, Session 6

Performance evaluation of medical LCD displays using 3D channelized Hotelling observers

L. Platiša, Univ. Gent (Belgium); C. Marchessoux, Barco N.V. (Belgium); B. Goossens, W. R. Philips, Univ. Gent (Belgium)

High performance of the radiologists in the task of image lesion detection is crucial for successful medical practice. One relevant factor in clinical image reading is the quality of the medical display. With the current trends of stack-mode liquid crystal displays (LCDs), the slow temporal response of the display plays a significant role in image quality assurance. In this paper, we report on the experimental study performed to evaluate the quality of a novel LCD with advanced temporal response compensation, and compare it to an existing state-of-the-art display of the same category but with no temporal response compensation. The data in the study comprise real clinical digital tomosynthesis images of the breast with added simulated mass lesions. The detectability for the two displays is estimated using the recent multi-slice channelized Hotelling observer (msCHO) model which is especially designed for multi-slice image data. Our results suggest that the novel LCD allows higher detectability than the existing one. Moreover, the msCHO results are used to advise on the parameters for the follow up image reading study with real medical doctors as observers. Finally, the main findings of the msCHO study were confirmed by a human reader study (details to be published in a separate paper).

7966-29, Session 6

Visual cues do not improve skin lesion ABC(D) grading

M. Zanotto, L. Ballerini, B. Aldridge, R. B. Fisher, J. Rees, The Univ. of Edinburgh (United Kingdom)

In this work evidence is presented supporting the hypothesis that observers tend to evaluate very differently the same properties of given skin-lesion images. Results from previous experiments have been compared to new ones obtained where we gave additional prototypical visual cues to the users during their evaluation trials. Each property (Colour, Colour Uniformity, Asymmetry, Border Regularity, Roughness of Texture) had to be evaluated on a 0--10 range, with both linguistic descriptors and visual references at each end and in the middle (e.g. light/medium/dark for colour). A set of twenty images covering different clinical diagnoses has been used in the comparison with previous results. Statistical testing showed that only for a few test images the inclusion of the visual anchors reduced the variability of the answers for some of the properties. Despite such reduction, though, the average variance of each property still remains high after the inclusion of the visual anchors. When considering each property, the average variance significantly changed for the Roughness of Texture, where the visual references caused an increase in the variability. With these results we can conclude that the variance of the answers observed in the previous experiments were not due to the lack of a standard definition of the extrema of the scale, but rather to a high variability in the way observers perceive and understand skin-lesion images.

7966-30, Session 6

The effect of defect cluster size and interpolation on radiographic image quality

K. Töpfer, K. L. Yip, Carestream Health, Inc. (United States)

For digital X-ray detectors, the need to control factory yield and cost invariably leads to the presence of some defective pixels. Recently, a standard procedure was developed to identify such pixels for industrial applications. However, no quality standards exist in medical or industrial imaging regarding the maximum allowable number and size of detector defects. While the answer may be application specific, the minimum requirement for any defect specification is that the diagnostic quality of the images be maintained. A more stringent criterion is to keep any changes in the images due to defects below the visual threshold. Two highly sensitive image simulation and evaluation methods were employed to specify the fraction of allowable defects as a function of defect cluster size in general radiography. First, the most critical situation of the defect being located in the center of the disease feature was explored using image simulation tools and a previously verified human observer model, incorporating a channelized Hotelling observer. The detectability index d' was obtained as a function of defect cluster size for three different disease features on clinical lung and extremity backgrounds. Second, four concentrations of defects of four different sizes were added to clinical images with subtle disease features and interpolated. Twenty observers evaluated the images against the original on a single display using a 2-AFC method, which was highly sensitive to small changes in image detail. The fraction of allowed defects was specified as a function of cluster size based on a 50% just-noticeable difference.

7966-31, Session 6

Verification of the QUBYX perfectlum calibration software using a PR-670 spectro radiometer and associated color management and verification facility

H. Roehrig, S. F. Hashmi, The Univ. of Arizona (United States)

At the University of Arizona a research project is underway which addresses consistent color and consistent gray-scale reproduction for digital color displays used in medical image interpretation, specifically for Pathology. Since there were no validated methods available in the field to reliably calibrate color displays, a laboratory was built which uses equipment capable of developing and implementing a color calibration protocol. The resulting facility essentially permits the University of Arizona to enter the field of ICC Profiling and Color Management, a subject area which is a novelty in the field of Medical Imaging. The facility includes a windows XP system, an NVIDIA graphic board and multiple medical grade displays. One of the highlights is a state of the art Spectro-Radiometer PR-670. The objective of the Spectro-Radiometer is to be involved in display calibration as well as in verification tasks.

For our experiment we concentrated on verification of the QUBYX PerfectLum Calibration Software. The specific objectives were:

1. Verify if the "PerfectLum" software from "Qubyx Ltd." would calibrate an LCD Display to DICOM GSDF part 14 standards. FIT and LUM tests were performed to verify the conformance and the deviation was quantified.

2. On the calibrated display, quantitative evaluation of Luminance response was done and deviation was quantified. Also the deviation was checked for class A or class B threshold, 10% and 20% deviation respectively.

3. Verify if the "Display Conformance" function in "PerfectLum" software returns the correct values for FIT, LUM and AAPM luminance response

test.

With respect to results all three objectives were met and PerfectLum calibrated display confirmed to the AAPM TG18 standards.

7966-32, Session 7

A study of attentional effects of intensity transforms for mammograms

A. J. Maeder, Univ. of Western Sydney (Australia)

Previous work has investigated effects of varying intensity on attraction of visual attention in general images, but little systematic work has occurred for medical images and especially mammograms (which may be amongst the most susceptible to such variations, due to the highly textured nature of the image content). This paper presents a study of the attentional effects of two specific types of intensity variation upon observer behaviour when viewing mammograms, namely intensity distribution normalisation between images acquired from different sources, and image intensity histogram equalisation for the non-background part of the images. 12 sets of 20 images each were randomly presented to 5 unskilled and 1 skilled observer over periods of 5 minutes with a fixed display time of 5 seconds per image followed by 5 seconds of blank screen. The viewing patterns for the observers were captured using an Eyetech eye tracker and reduced to the first five locations of fixations to establish the attentional attractors. For the set of unskilled observers, some systematic attraction of attention towards the highest intensity regions of the images for the brighter normalised images is observed proportional to the amount of intensity increase. For the uniform distribution variation, this effect is far less marked but is still detected. For the single skilled observer, no significant disruption of attentional patterns during viewing is observed. The difference between unskilled and skilled observer behaviour emphasizes the need to conduct studies for clinical applications with skilled observers, as their habits and responses are different due to training and knowledge of the image contents.

7966-33, Session 7

The impact of clinical indications on visual search behaviour in skeletal radiographs

A. Rutledge, M. F. McEntee, L. A. Rainford, M. J. O'Grady, K. McCarthy, M. Butler, Univ. College Dublin (Ireland)

Hazards associated with ionizing radiation are documented and therefore justifying the need for X-ray examinations has come to the forefront of the radiation safety debate in recent years. International legislation states that the referrer is responsible for the provision of sufficient clinical information to enable the justification of the exposure. Clinical indications are a set of systematically developed statements to assist in accurate diagnosis and appropriate patient management. In this study, the impact of clinical indications upon satisfaction of search for musculoskeletal radiographs is analyzed. A group of clinicians (n=6) interpreted musculoskeletal radiology cases (n=33) with and without clinical indications. Radiographic images were selected to represent common musculoskeletal trauma presentations. Fracture detection was measured using ROC methodology. An eye tracking device was employed to record clinicians search behavior by analyzing distinct fixation points and search patterns. Influence of clinical information on fracture detection and search patterns was assessed. Provisional findings of this study demonstrate that the inclusion of clinical indications result in impressionable search behavior with greater degree of confidence in diagnosis reported. Search patterns with clinical indications may not prove optimal as differences in eye tracking parameters were noted. Full results and conclusions will be presented. This study attempts to uncover fundamental observer search strategies and behavior with and without clinical indications, thus providing a greater understanding into the image interpretation process for musculoskeletal trauma.

7966-34, Session 7

Measurement of breast lesion display luminance and overall image display luminance relative to optimum luminance for contrast perception

M. A. Rawashdeh, W. Lee, P. C. Brennan, W. Reed, M. F. McEntee, R. Bourne, The Univ. of Sydney (Australia)

When radiologist is adapted to a specific luminance, around 100cd/m2, the perceived contrast response is maximal, and is markedly reduced for regions with higher or lower luminance. This adaptation state allows the eye to respond to the greatest number of grey levels, to be able to detect subtle differences. This study examines the relationship between average monitor and breast tissue luminance relative to the optimum contrast perception. A set of 42 mammograms was used to assess overall image luminance. Each image displayed on the monitor was divided into 16 equal regions. The luminance at the midpoint of each region was measured using a calibrated photometer and the overall image luminance was calculated. Average breast tissue display luminance was calculated from the subset of regions containing only breast tissue. Lesion display luminance was compared with both overall image display luminance and average breast tissue display luminance. Statistically significant differences ($p<0.0001$) were noted between overall image display luminance (4.3±0.7 cd/m2) and lesion display luminance (15.0±6.8 cd/m2); and between average breast tissue display luminance (6.8±1.3 cd/m2) and lesion display luminance ($p<0.002$). Findings from this study also demonstrate that the display luminance of lesion, overall image and breast tissue fell below the level for maximum contrast sensitivity. Also the lesion display luminance was significantly higher than the overall image and breast tissue display luminance. Based on these results, it can be argued that breast lesion detection may be enhanced by the use of brighter monitor displays.

7966-35, Session 7

Motion perception in medical imaging

F. Massanes, J. G. Brankov, Illinois Institute of Technology (United States)

A potential drawback of image noise suppression in medical image sequence processing is the possible loss of the apparent motion: making objects appears to move slower or less then they move in the reality. For medical imaging application this can be of critical importance, for example myocardium motion in cardiac gated Single photon emission computed tomography (SPECT) imaging can differentiate viable muscle from a scar tissue. Therefore in this work we design a set of experiments to measure how human observers perceive apparent motion in presence of image degradation by noise and blur. In addition we will try to indentify relevant image features, based on visual attention model and block matching motion estimation methods that would allow development of an accurate numerical observer capable of predicting human observer motion perception.

7966-36, Session 7

Characterizing non-Gaussian properties of breast images with a noisy-Laplacian distribution

C. K. Abbey, Univ. of California, Santa Barbara (United States) and Univ. of California, Davis (United States); A. Nosratieh, UC Davis Medical Ctr. (United States); S. Zhang, M. P. Eckstein, Univ. of California, Santa Barbara (United States); J. M. Boone, UC Davis Medical Ctr. (United States)

In the field of natural scene statistics, higher-order statistical properties

have been found to represent independent components of visual scenes. This finding appears to give important insights into the design and function of visual perception in humans. We are interested in using a similar analysis to evaluate the role of image statistics on perception in x-ray images of the breast, where transport phenomena such as transmission and superposition (instead of reflection and occlusion) result in fundamentally different statistical properties.

A ubiquitous finding in natural scenes is a two-sided Laplacian distribution characterizing the responses to Gabor filters. However, when we apply these filters to x-ray mammograms, we find that the response distribution lacks the cusp in the center of the Laplacian distribution. We believe that this is due to the superposition of anatomy in such images as well as the influence of photon noise.

The purpose of this research is to describe a modified distribution we refer to as a noisy-Laplacian distribution, which we propose as a more appropriate model for responses to breast images. The distribution is generated by the sum of a Laplacian-distributed random variable with an independent Gaussian random variable. We give the mathematical description of the distribution as well as measures of the departure from a pure Gaussian distribution. We demonstrate the use of the distribution on a limited set of projection mammograms.

7966-37, Session 8

Improved implementation of the abnormality manipulation software tools

M. T. Madsen, K. S. Berbaum, K. M. Schartz, R. T. Caldwell, The Univ. of Iowa Hospitals and Clinics (United States)

Collecting clinical cases for medical imaging perception studies is often challenging. Few clinical images are free of benign abnormalities which may affect observers in unpredictable ways and the location of desired target abnormalities may not be ideal for specific experiments. We have developed a suite of software tools for manipulating medical tomographic image sets that overcome these difficulties. In our initial development, abnormalities were removed or inserted on a slice-by-slice basis. We have found in some cases that this approach leaves artifacts when the orthogonal image sets are viewed. To circumvent that problem, the tools have been redesigned so that they operate in three dimensions. An operator uses an ellipsoid mask to select the removal and the replacement areas. As in the previous implementation, only the mask is smoothed (but now in three dimensions) so there are no discernible edge artifacts when the removed and replaced areas are added together. Performing these operations in three dimensions eliminates slice-to-slice artifacts that are obvious in orthogonal views and has the additional benefit of reducing the total manipulation time. This new approach has been validated on PET data sets where alterations were made on axial slices while the experimental validation was performed with coronal slices. This approach has also been implemented for CT studies.

7966-38, Session 8

A clinical image preference study comparing digital tomosynthesis with digital radiography for pediatric spinal imaging

J. King, CancerCare Manitoba (Canada); I. A. Elbakri, CancerCare Manitoba (Canada) and Univ. of Manitoba (Canada); M. H. Reed, J. Wrogemann, The Children's Hospital of Winnipeg (Canada)

The purpose of this study was to evaluate the diagnostic quality of digital tomosynthesis (DT) images for pediatric imaging of the spine. We performed a phantom image rating study to assess the visibility of anatomical spinal structures in DT images relative to digital radiography (DR) and computed tomography (CT). We collected DT and DR images of the cervical, thoracic and lumbar spine using anthropomorphic phantoms. Four pediatric radiologists and two residents rated the visibility of structures on the DT image sets compared to DR using a four point scale (0 = not visible; 1 = visible; 2 = superior to DR; 3 = excellent, CT unnecessary). In general, the structures in the spine received ratings between 1 and 3 (cervical), or 2 and 3 (thoracic, lumbar), with a few mixed scores for structures that are usually difficult to see on diagnostic images, such as vertebrae near the cervical-thoracic joint and the apophyseal joints of the lumbar spine. The DT image sets allow most critical structures to be visualized as well or better than DR. When DR imaging is inconclusive, DT is a valuable tool to consider before sending a pediatric patient for a higher-dose CT exam.

7966-39, Session 8

Computer-aided detection as a decision assistant in chest radiography

M. R. Samulski, P. R. Snoeren, B. Platel, B. van Ginneken, L. E. Hogeweg, Radboud Univ. Nijmegen Medical Ctr. (Netherlands); C. M. Schaefer-Prokop, Meander Medisch Centrum (Netherlands); N. Karssemeijer, Radboud Univ. Nijmegen Medical Ctr. (Netherlands)

Contrary to what may be expected, finding abnormalities in complex images like pulmonary nodules in chest radiographs is not dominated by time-consuming search strategies but by an almost immediate global interpretation. This was already known in the nineteen-seventies from experiments with briefly flashed chest radiographs. Later on, experiments with eye-trackers showed that abnormalities attracted the attention quite fast but often without further reader actions. Prolonging one's search seldom leads to newly found abnormalities and may even increase the chance of errors. The problem of reading chest radiographs is therefore not dominated by finding the abnormalities, but by interpreting them. This suggests that readers could benefit from computer-aided detection (CAD) systems not so much by their ability to prompt potential abnormalities, but more from their ability to 'interpret' the potential abnormalities. In this paper, this hypothesis was investigated by an observer experiment. In one condition, the traditional CAD condition, the most suspicious CAD locations were shown to the subjects, without telling them the levels of suspiciousness according to CAD. In the other condition, interactive CAD condition, levels of suspiciousness were given, but only when readers requested them at specified locations. These two conditions focus on decreasing search errors and decision errors, respectively. Results of reading without CAD were also recorded. Six subjects, all non-radiologists, read 223 chest radiographs in both conditions. CAD results were obtained from the OnGuard 5.0 system developed by Riverain Medical (Miamisburg, Ohio). The observer data were analyzed by Location Response Operating Characteristic analysis (LROC). It was found that: 1) With the aid of CAD, the performance is significantly better than without CAD; 2) The performance with interactive CAD is significantly better than with traditional CAD at low false positive rates.

7966-40, Session 8

Does stereo-endoscopy improve neurosurgical targeting in 3rd ventriculostomy?

K. Abhari, Robarts Research Institute (Canada) and The Univ. of Western Ontario (Canada); S. de Ribaupierre, The Univ. of Western Ontario (Canada); T. M. Peters, R. A. Eagleson, Robarts Research Institute (Canada) and The Univ. of Western Ontario (Canada)

Endoscopic third ventriculostomy is a minimally invasive surgical technique to treat hydrocephalus; a condition where patients suffer from excessive amounts of cerebrospinal fluid (CSF) in the ventricular system of their brain. This technique involves using a monocular endoscope to locate the third ventricle, where a hole can be made to drain excessive fluid. Since a monocular endoscope provides only a 2D view, it is difficult to make this perforation due to the lack of monocular cues and

depth perception. In a previous study, we had investigated the use of a stereo-endoscope to allow neurosurgeons to locate and avoid hazardous areas on the surface of the third ventricle. In this paper, we extend our previous study by developing a new methodology to evaluate the targeting performance in piercing the hole in the membrane. We consider the speed and accuracy of this surgical task and derive an index of performance for a task which does not have a well-defined position or width of target. Our performance metric is sensitive and can distinguish between experts and novices. We make use of this metric to demonstrate an objective learning curve on this task for each subject.

7966-41, Session 8

An analysis of the impact of tumor amount on the predictive power of a prostate biopsy prognostic assay

F. M. Khan, S. Fogarasi, D. Powell, G. Fernandez, R. Mesa-Tejada, M. J. Donovan, Aureon Biosciences, Inc. (United States)

The Prostate Px+ prognostic assay offered by Aureon Biosciences is designed to predict progression post primary treatment for prostate cancer patients based on their diagnostic biopsy specimen. The assay is driven by the automated image analysis of a diagnostic prostate needle biopsy (PNB) and incorporates pathologist acquired and digitally masked images which reflect the morphometric (Hematoxylin and Eosin, H&E) and protein expression (immunofluorescent, IF) properties of the PNB. Up to 9 images (3 H&E and 6 IF) from each of 1027 patients, with varying amounts of tumor content were included in the study. We wanted to understand what was the minimal tumor volume required to maintain assay predictive robustness as a result of overall PNB tumor content and assess the impact of pathologist tumor masking variability.

232 patients were selected who had a minimum of 80% tumor volume in a 20x magnification image. In each of the three imaging domains (2 different multiplex (Mplex) (IF) images and one H&E), the tumor volume was artificially reduced in increments from 80% to 2.5% of the original image area. This simulated decreasing amounts of tumor as well as variations in digital tumor masking.

The univariate predictive power of individual imaging domains remained robust down to the 10% tumor level, whereas the total assay was robust through the 20% to 10% tumor level. This work presents one of the first assessments of the variety in tumor amounts on the predictive power of a commercially available prognostic assay that is reliant on multiple bioimaging domains.

7966-42, Session 8

Quantitative assurance of optical image quality of rigid endoscopes, results from five years clinical experience

H. J. Noordmans, R. Wientjes, W. Mulder, H. Belkadi, H. van den Brink, Univ. Medical Ctr. Utrecht (Netherlands)

To guarantee the optical quality of rigid endoscopes in clinical practice, a test bench has been developed to measure the illumination pathway using a white LED and photo cell and the viewing pathway using a LCD generated test pattern and high resolution camera. By storing the results into a database changes in quality can be followed over time. In this talk the results are presented of one year of measurements at the Hospital Sterilisation and Disinfecting Unit after cleaning and before sterilization. In total more than 400 measurements were performed on 119 rigid endoscopes of 28 different types.

The clinically used endoscopes appeared to degrade slowly (but sometimes suddenly) over time, on the average 20% degradation for the illumination fibers and 10% for the lens quality. As expected brand new endoscopes have a better quality compared to clinically used endoscopes of the same type. However, one new endoscope performed less and was returned to the manufacturer for inspection. Endoscopes returned from repair were better than used endoscopes but could not be restored to the quality of new endoscopes. Remarkably, the quality of repaired endoscopes dropped quickly within the first months after clinical use.

The use of a test bench to monitor the optical quality of endoscopes over time shows to be a valuable investment that will contribute to the quality of patient treatment. More research is required to reveal the cause of degradation and improve the significance and accuracy of the measurements.

Conference 7967: Advanced PACS-based Imaging Informatics and Therapeutic Applications

Wednesday-Thursday 16-17 February 2011 • Part of Proceedings of SPIE Vol. 7967 Medical Imaging 2011: Advanced PACS-based Imaging Informatics and Therapeutic Applications

7967-01, Session 1

Brain-behavior correlates of neurorehabilitation: challenges and opportunities for transformational interdisciplinary collaborations

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Brain-behavior correlates of neurorehabilitation-the ultimate frontier is to identify biomarkers through neuro-imaging techniques at relevant time points (e.g., early after stroke) that are valid and reliable predictors of: 1) responsiveness to targeted neurorehabilitation interventions and 2) important functional recovery outcomes (e.g., reach/grasp and walking). Current research has begun to identify potential biomarkers through various functional and structural neuroimaging (e.g., MRI, DTI, and fMRI), neurophysiological (evoked potentials using Transcranial Magnetic Stimulation), behavioral measures (e.g., trajectory analysis) and clinical measures [1] [2] [3, 4]. However, in the case where only one cerebral hemisphere is damaged rendering the individual hemiparetic after a cerebral stroke, an effective path toward optimal recovery is not well understood. This is further complicated by lesion-induced changes in inter-hemispheric inhibition (IHI) that further inhibits the damaged hemisphere, and important behavioral factors including motivational mediators such as self-efficacy, environmental context and persistent compensatory behavior (e.g., substituting the good limb) that emerges from learned non-use of the paretic limb. Thus, the challenge becomes one of extracting and integrating relevant information from moderate to large cross-sectional, and longitudinal datasets obtained from multiple sources and contexts (i.e., laboratory studies; multi-site randomized controlled trial), while at the same time maintaining a level of individual participant data that captures important individual differences. We will use examples from several the large multi-site randomized controlled trials [5, 6] and several smaller clinical studies [7-9] to illustrate the various forms of data (imaging and behavioral) and the challenges and opportunities for interdisciplinary collaboration.

References:

[1] Cramer SC, Shah R, Juranek J, Crafton KR, Le V. Activity in the peri-infarct rim in relation to recovery from stroke. Stroke. 2006 Jan;37(1):111-5.

[2] Dong Y, Dobkin BH, Cen SY, Wu AD, Winstein CJ. Motor cortex activation during treatment may predict therapeutic gains in paretic hand function after stroke. Stroke. 2006 Jun;37(6):1552-5.

[3] Stinear CM. Prediction of recovery of motor function after stroke. Lancet Neurology. 2010;9:1228-32.

[4] Stinear CM, Barber A, Smale PR, Coxon JP, Fleming MK, Byblow WD. Functional potential in chronic stroke patients depends on corticospinal tract integrity. Brain. 2007;130:170-80.

[5] Harvey R, Winstein CJ. Design for the Everest Randomized Trial of Cortical Stimulation and Rehabilitation for Arm Function Following Stroke. Neurorehabil Neural Repair. 2008.

[6] Winstein CJ, Miller JP, Blanton S, Taub E, Uswatte G, Morris D, et al. Methods for a multisite randomized trial to investigate the effect of constraint-induced movement therapy in improving upper extremity function among adults recovering from a cerebrovascular stroke. Neurorehabil Neural Repair. 2003 Sep;17(3):137-52.

[7] James GA, Lu ZL, VanMeter JW, Sathian K, Hu XP, Butler AJ. Changes in resting state effective connectivity in the motor network following rehabilitation of upper extremity poststroke paresis. Top Stroke Rehabil. 2009 Jul-Aug;16(4):270-81.

[8] Winstein CJ, Rose DK, Tan SM, Lewthwaite R, Chui HC, Azen SP. A randomized controlled comparison of upper-extremity rehabilitation strategies in acute stroke: A pilot study of immediate and long-term outcomes. Arch Phys Med Rehabil. 2004 Apr;85(4):620-8.

[9] Koski L, Lin JC, Wu AD, Winstein CJ. Reliability of intracortical and corticomotor excitability estimates obtained from the upper extremities in chronic stroke. Neurosci Res. 2007 May;58(1):19-31.

7967-02, Session 1

Combined semantic and similarity search in medical image databases

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The current diagnostic process at hospitals is mainly based on reviewing and comparing images coming from multiple time points and modalities in order to monitor disease progression over a period of time. However, for diminished cases the radiologist deeply relies on reference literature or second opinion. Although there is a vast amount of acquired images stored in PACS systems which could be reused for decision support, these data sets suffer from weak search capabilities. Thus, we present a search methodology which enables the physician to fulfill intelligent search scenarios on medical image databases combining ontology based semantic and appearance based similarity search. With that we could eliminate 13% of the top ten hits which would arise without taking the semantic context into account.

7967-03, Session 1

Automatic semantic annotation and validation of anatomy in DICOM CT images

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In the current healthcare environment, the time available for physicians to browse images is shrinking due to increase in the amount of images. This is further aggravated by mounting pressure to become more productive in the face of decreasing reimbursement. Hence, there is an urgent need to deliver technology which enables faster navigation through effortless image sub-volume visualization.

Annotating image regions with semantic labels (such as those derived from the RADLEX ontology) can vastly enhance image navigation and sub-volume visualization. Popular, automated image annotation approaches involve atlas-based methods or the application of computationally intensive image classifiers.

This paper uses a random regression forest algorithm for the efficient, automatic detection and localization of anatomical structures within DICOM 3D CT scans. A regression forest is a collection of regression trees which are trained to achieve direct mapping from voxels to organ location and size, in a single pass. Quantitative validation is performed on a database of approximately 50 highly variable CT scans. Initial investigations show that localization errors are lower (and more stable) than those achieved by state-of-the art-global registration approaches.

The algorithm's simplicity of its context-rich visual features yield typical runtimes of less than 10 seconds for a 512^3 slice DICOM CT series on a single-threaded, single-core windows machine running on multiple trees; each tree taking less than a second. Validation of the automated labeling is being performed by comparison against ground-truth annotated by a human expert. The navigational improvements facilitated by this technology on conventional PACS systems are also demonstrated.

7967-04, Session 1

The utility of rapid database searching for quality assurance: 'detective work' in uncovering radiology coding and billing errors

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When the first quarter of 2010 Department of Radiology statistics were provided to the Section Chiefs, ours was alarmed to discover that Ultrasound showed a decrease of 2.5 percent in billed examinations. This seemed to be in direct contradistinction to the experience of the ultrasound faculty members and sonographers. Their experience was that they were far busier than during the same quarter of 2009. The one exception that all acknowledged was the month of February, 2010 when several major winter storms resulted in a much decreased Hospital admission and Emergency Department visit rate. Since these statistics in part help establish priorities for capital budget items, professional and technical staffing levels, and levels of incentive salary, they are taken very seriously.

The availability of a desktop, Web-based RIS database search tool developed by two of the authors (WK, WB) and built-in database functions of the ultrasound miniPACS, made it possible for us very rapidly to develop and test hypotheses for why the number of billable examinations was declining in the face of what experience told us was an increasing number of examinations being performed. Within a short time, we identified the major cause as errors on the part of the company retained to verify billable CPT codes against ultrasound reports. This information is being used going forward to recover unbilled examinations and take measures to reduce or eliminate the types of coding errors that resulted in the problem.

7967-05, Session 2

Multiscale salient point-based retrieval of fracture cases

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Many people suffer from a fracture and a surgical intervention is sometimes needed. There is a decision to be made on what type of intervention could be used. An overview of past cases and associated surgical techniques used can help surgeons to make a decision.

Images play an important role for surgeons to find out the nature of a fracture and to plan an adapted surgical intervention. As images are often stored based on patient cases, the common way to access to images is based on patient identification. Content-based image retrieval (CBIR) is a technique to retrieve images by computing visual similarity, which provides an alternative choice for surgeons to access past cases.

In a preliminary study, we used pixel-grid based salient-point features to build a first prototype of case-based visual retrieval of fracture cases. Cases belonging to different fracture classes were sometimes confused due to the similar bone structures presented in images.

In this work, a multi-scale approach is used in order to perform similarity measures at both large and small scales. When compared to the first prototype, the introduction of scale and spatial information allowed improving the performance of the system. Cases containing similar bone structures but with unexpected fractures are less returned.

7967-06, Session 2

Using relevant regions in image search and query refinement for medical CBIR

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In clinical decision processes, relevant scientific publications and their associated medical images can provide valuable and insightful information. However, effectively searching through both text and image data is a difficult and arduous task. More specifically in the area of image search, finding similar images (or regions within images) poses another significant hurdle for effective knowledge dissemination. Thus, we propose a method using local regions within images to perform and refine the results in medical image CBIR. Our system is built upon the ITSE system developed by the Image and Text Integration (ITI) group at the National Library of Medicine (NLM). The ITSE system effectively narrows down the relevant images from which our region-based method can be effective. In our first example, we define and extract large, characteristic regions within an image, and then show how to use these regions to match a query image to similar content. In our second example, we enable the formulation of a mixed query based upon text, image, and region information, to better represent the end user's search intentions. Given our new framework for region-based queries, we present re-ranked search results that improves upon the set of similar results.

7967-07, Session 2

Is there a need for biomedical CBIR systems in clinical practice?: outcomes from a usability study

S. K. Antani, Z. Xue, L. R. Long, D. Bennett, S. Ward, G. R. Thoma, National Library of Medicine (United States)

There is great interest in the development of software tools to support diagnosis, research and education of cervical cancer. In collaboration with the National Cancer Institute (NCI), the National Library of Medicine (NLM) maintains a large collection of cervical images (cervigrams) and related anonymized patient data toward developing a suite of tools to analyze, annotate, and search the data. One such tool is the prototype Content Based Image Retrieval (CBIR) system, called CervigramFinder. It retrieves cervigrams based on the visual similarity of the characteristics of particular regions on the cervix. We have used this system to study several obstacles/gaps which hamper practical use of image retrieval systems during routine clinical medicine, research, or education. In this paper, we report on steps taken in the development of CervigramFinder toward minimizing gaps identified in a prior study by the authors. Specifically, we discuss our work on the usability test carried out on a large colposcopic and cervical pathology conference as a model toward evaluating acceptance of such technology into routine clinical practice.

7967-08, Session 2

Development of a data mining and imaging informatics display tool for a multiple sclerosis e-folder system

M. Liu, J. Loo, K. C. Ma, B. J. Liu, The Univ. of Southern California (United States)

Multiple sclerosis (MS) is a debilitating autoimmune disease of the central nervous system that damages axonal pathways through inflammation and demyelination. In order to address the need for a centralized application to manage and study MS patients, the MS e-Folder-a web-based, disease-specific electronic medical record system-was

developed. The e-Folder is a PHP and MySQL based graphical user interface (GUI) that can serve as both a tool for clinician decision support and a data mining tool for researchers. This web-based GUI gives the e-Folder a user friendly interface that can be securely accessed through the internet and requires minimal software installation on the client side. The e-Folder GUI displays and queries patient medical records--including demographic data, social history, past medical history, and past MS history. In addition, DICOM format imaging data, and computer aided detection (CAD) results from a lesion load algorithm are also displayed. The GUI interface is dynamic and allows manipulation of the DICOM images, such as zoom, pan, and scrolling, and the ability to rotate 3D images. Given the complexity of clinical management and the need to bolster research in MS, the MS e-Folder system will improve patient care and provide MS researchers with a function-rich patient data hub.

7967-09, Session 2

Development of automated detection of radiology reports citing incidental adrenal findings

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Incidental findings on imaging studies are unanticipated findings that are unrelated to the reason for ordering the exam. Indeterminate incidental findings pose a special challenge to both radiologist and the ordering physician as their imaging appearance is potentially harmful but their clinical significance and optimal management is unknown. Adrenal nodules are an example of a commonly encountered indeterminate incidental finding on cross sectional imaging. These nodules are detected in up to 5% of CT examinations (1). Once visualized, ordering physicians often feel compelled to follow-up these nodules with further testing because of their potential to represent metastatic disease from an unknown primary or functioning nodules.

We seek to determine if it is possible to automate detection of adrenal nodules, an indeterminate incidental finding, on imaging examinations at our institution by identifying what phrases radiologists employ to describe these findings. Using PRESTO (Pathology-Radiology Enterprise Search tool) (2), a newly developed search engine at our institution that mines dictated radiology reports, we searched for phrases commonly used by attendings to describe incidental adrenal findings. Using these phrases as a guide, we designed an incidental finding query that can be used with the PRESTO index. The results were further refined using a modified version of the NegEx to eliminate query terms that have been explicitly negated within the report text. This query allows us to quantify the prevalence of these indeterminate incidental adrenal findings at our institution. Subsequently, this query can be combined with electronic medical record data searches to determine the clinical significance of these findings through follow-up.

7967-10, Session 2

Automated BI-RADS 3 follow-up application: improving patient care and compliance

P. Kandula, T. S. Cook, W. Boonn, W. Kim, The Univ. of Pennsylvania Health System (United States)

With the current emphasis on healthcare reform and cost effectiveness, methods to increase healthcare efficiency while improving outcomes are paramount. With reference to breast cancer, delay in diagnosis can cause significant morbidity and mortality, as well as increased long term health care costs. Assessment with short interval mammographic follow-up of BI-RADS 3 lesions has been shown to increase detection of a small number of breast cancers at an early stage. Because of the importance of timely follow-up for these patients, we propose a novel computer application that identifies patients due for short-term mammographic follow-up, thus reducing costly hours spent by personnel, reducing human error, and improving patient compliance.

Our web-based application mines radiology reports and scheduling information to generate lists of patients due for short-term mammographic follow-up of BI-RADS 3 category results. The results can be placed in a worklist that can be used by a staff member to contact patients to schedule follow-up appointments. Additional analytic features of the application can identify referral characteristics that may serve as potential sources for improvement of patient follow-up.

We believe that an automated system can be designed to improve patient care and compliance with follow-up of BI-RADS category 3 results.

7967-30, Poster Session

Improvement of MS (multiple sclerosis) CAD (computer aided diagnosis) performance using C/C++ and computing engine in the graphical processing unit (GPU)

J. Suh, N. Eliyahoo, K. C. Ma, A. H. Le, B. J. Liu, The Univ. of Southern California (United States)

Multiple Sclerosis (MS) is a disease which is caused by damaged myelin around axons of the brain and spinal cord. Currently, MR Imaging is used for diagnosis, but it is very highly variable and time-consuming since the lesion detection and estimation of lesion volume are performed manually. For this reason, we developed a CAD (Computer Aided Diagnosis) system which would assist segmentation of MS to facilitate physician's diagnosis. The MS CAD system utilizes K-NN (k-nearest neighbor) algorithm to detect and segment the lesion volume in an area based on the voxel. The prototype MS CAD system was developed under the MATLAB environment. Currently, the MS CAD system consumes a huge amount of time (approximately 10 hours for one MS case) to process data. In this paper we will present the development of a second version of MS CAD system which is converted into C/C++ in order to take advantage of GPU (Graphical Processing Unit) which will provide parallel computation. With the realization in C/C++ and using GPU, we expect to cut running time drastically. The paper investigates the conversion from MATLAB to C/C++ and the utilization of a high-end GPU for parallel computing of data to improve algorithm performance of MS CAD. Lessons learned and pitfalls will also be discussed to avoid similar mistakes in the future when developing image processing algorithms with heavy computational time demands. The result of this study will show the effectiveness and benefits of this second version of MS CAD on MS diagnosis.

7967-31, Poster Session

Content-based image retrieval with semantic navigation for medical images with multifocal diseases in integrated RIS/PACS system

Y. Zhu, J. Zhang, Shanghai Institute of Technical Physics (China)

In this paper, we proposed a novel architecture integrated with RIS/PACS system that combined image annotation, CBIR techniques and high-dimensional index to retrieve similar medical images with one or more relevant focus in large scale medical image database. In our designed system, regions of interest (ROIs) were labeled by symptom descriptions found in relevant radiology reports as semantic navigation. The annotations were saved as xml file with image makeup language (IML). Then low level features such as texture and statistic features were extracted from the ROIs of lesions and inserted into a database. Recursive feature elimination algorithm was applied to find a high performance feature subset for each symptom. The high performance subset features were used to build high dimensional index with semantic labels guiding the searching path as the navigation. As there might be more than one focus in one image, weight values specified by the user were introduced to calculate the final similarities. The searching results of medical images with multifocal diseases are likely to have the same

pathologies and visual effects with example image and are valuable for imaging diagnosis. Comparing this system with traditional CBIR without semantic navigation and high dimensional index, the time spent on distance computations reduces greatly when the index database grows larger. The system was implemented for lung CT images, but it could be easily extended to other organs.

7967-32, Poster Session

DICOM structured report to track patient's radiation dose to organs from abdominal CT exams

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The dramatic increase of diagnostic imaging capabilities over the past decade has contributed to increased radiation exposure to patient populations. Several factors have contributed to the increase in imaging procedures: wider availability of imaging modalities, increase in technical capabilities, rise in demand by patients and clinicians, favorable reimbursement, and lack of guidelines to control utilization. The primary focus of this research is to provide in depth information about radiation doses that patients receive as a result of CT exams, with the initial investigation involving abdominal CT exams. Current dose measurement methods (i.e. CTDIvol Computed Tomography Dose Index) do not provide direct information about organ dose. We recently reported on a method to determine CTDIvol normalized organ doses using a set of organ specific exponential regression equations of the form (A,B fitting parameters, p=patient perimeter). These were used together with measured CTDIvol to calculate organ dose estimates from abdominal CT scans for eight different patient models (from GSF - German National Research Center for Environment and Health). For each patient, organ dose and CTDIvol (to a 32 cm diameter phantom) were estimated for an abdominal CT scan. We then developed a DICOM Structured Report to store the pertinent patient information on radiation dose to their abdominal organs. Our model is based on the ACR index for radiation dose along with added other DICOM fields to complete the patient profile for organ dose estimation.

7967-33, Poster Session

Visualization index for image-enabled medical records

W. Dong, J. Sun, W. Zheng, J. Zhang, Shanghai Institute of Technical Physics (China)

In this paper, we designed a system to provide visualization index for patient medical records stored in medical information systems. To transform the text- or image-based medical information into easily understandable and acceptable form for human, two object-oriented human information models were developed. One model is used to parse and classify medical records stored in medical information systems based on the descriptions of diseases and body part examined involved. With this model, all indexes of related medical records were managed and represented by anatomical objects based on the medical record content and their anatomical locations. The other is developed to visualize 3D index information distributed in human body about the patient medical records. We assigned an anatomical structure object to every patient to store indexes of the patients' basic information, historical examined image information and RIS report information. When a doctor want to review patient historical records, he or she can first load anatomical structure object and view the 3D index of this anatomical structure object by using digital human model tool kit. With this prototype system, doctors can be easily and visually to get whole historical healthcare status of patients with large amount of medical data and quickly to find and point detailed information including both reports and images from medical information systems. In this way, doctors can save the time to understand the information, get a more comprehensive understanding of the patients' situations, and can provide better healthcare services to patients.

7967-34, Poster Session

Development of a user-centered radiology teaching file system

M. dos Santos, A. Fujino, Univ. de São Paulo (Brazil)

This work presents the development of a digital radiology teaching file. This proposal aims to provide services customized to users' contexts and their informational needs. The environment implements a distributed clinical database, including medical images, authoring tools, a repository for multimedia documents, and also a peer-reviewed model that assures dataset quality. The current implementation has shown that the creation of clinical data repositories on networked computer environments points to be a good solution in terms of the offering means to review management information practices in electronic environments and mediation with users connected to the system throughout electronic interfaces.

7967-35, Poster Session

A solution for archiving and retrieving preclinical molecular imaging data in PACS using a DICOM gateway

J. Lee, B. Liu, B. J. Liu, The Univ. of Southern California (United States)

Advances in biology, computer technology and imaging technology have given rise to a new scientific specialty referred to as molecular imaging, which is the in vivo imaging of cellular and molecular pathways using contrast-enhancing targeting agents. Increasing amounts of molecular imaging research is being performed at pre-clinical stages, generating data from these studies that need structured archiving and distribution solutions. Since PACS in radiology stores clinical DICOM formats, a method is proposed to convert imaging files from preclinical molecular imaging studies into DICOM formats for archival into PACS systems. Archiving preclinical molecular imaging data is made possible using our proposed DICOM conversion method, presented in the results, but there remains valuable preclinical metadata that is currently not yet supported in DICOM or PACS. In the discussion section, we present our experiences and suggestions on improving DICOM conformance from molecular imaging software vendors and also expanding PACS to incorporate more metadata from preclinical research.

7967-36, Poster Session

Teleradiology network system and computer-aided diagnosis workstation using the web medical image conference system with a new information security solution

H. Satoh, Tokyo Health Care Univ. (Japan)

We are studying the secret sharing scheme 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 share. Our method is called perfect secret sharing scheme(sss). Perfect secret sharing scheme(sss) can encode the confidential medical information to two or more share. Confidential Medical information passes a different information transportation route. However, when all share cannot be collected, the confidential

information cannot be decoded. We have developed the teleradiology network system that provided with perfect secret sharing scheme(sss) called "GFI E-Tally. Our teleradiology network system can perform Web medical image conference in the medical institutions of a remote place. Our teleradiology network system can perform Web medical image conference in the medical institutions of a remote place using the web medical image conference system with information security solution called "GFI E-Tally. Moreover, biometric face authentication system is connected with workstation of teleradiology network system. Biometric face authentication system analyzes the feature of the face image of which it takes a picture with the camera at irregular intervals and defends the safety of confidential medical information. We propose a new information transportation method and a new information storage method with a new information security solution. The results of this study indicate that our teleradiology network system can increase diagnostic speed, diagnostic accuracy, and personal information protection by using secret sharing scheme and personal authentication.

7967-11, Session 3

Towards building high performance medical image management system for clinical trials

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Medical image based biomarkers are being established for therapeutic cancer clinical trials, where image assessment is among the essential tasks. Large scale image assessment is often performed by a large group of experts by retrieving images from a centralized image repository to workstations to markup and annotate images. In such environment, it is critical to provide a high performance image management system that supports efficient concurrent image retrievals in a distributed environment. There are several major challenges: high throughput of large scaled image data on the server for multiple concurrent users, efficient communication protocols for transporting data, and effective management of versioning of data for audit trails. We study the major bottlenecks for such a system, propose and evaluate a solution by using a hybrid image storage of solid state disks and hard disks, RESTful Web Services based protocols for exchanging data, and a database based versioning scheme for efficient archiving image revision history.

Our experiments show promising results of our methods, and our work provides a guideline for building enterprise level high performance medical image management systems.

7967-12, Session 3

Transforming medical imaging applications into collaborative PACS-based telemedical systems

R. Maani, S. Camorlinga, N. Arnason, Univ. of Manitoba (Canada)

Telemedical systems are not practical for use in clinical workflows unless they are able to communicate with the Picture Archiving and Communications System (PACS). On the other hand, there are many medical imaging applications that are not developed as telemedical systems. Some medical imaging applications do not support collaboration and some do not communicate with the PACS and therefore limit their usability in clinical workflows. This paper presents a general architecture based on a three-tier architecture model. The architecture and the components developed within it, transform medical imaging applications into collaborative PACS-based telemedical systems. As a result, current medical imaging applications that are not telemedical, not supporting collaboration, and not communicating with PACS, can be enhanced to support collaboration among a group of physicians, be accessed remotely, and be clinically useful. The main advantage of the proposed architecture is that it does not impose any modification to the current medical imaging applications and does not make any assumptions about the underlying architecture or operating system.

7967-13, Session 3

Integrating medical imaging analyses through a high-throughput bundled resource imaging system

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Exploitation of advanced, PACS-centric image analysis and interpretation pipelines provides well-developed storage, retrieval, and archival capabilities along with state-of-the-art data providence, visualization, and clinical collaboration technologies. However, pursuit of integrated medical imaging analysis through a PACS environment can be limiting in terms of the overhead required to validate, evaluate and integrate emerging research technologies. Herein, we address this challenge through presentation of a high-throughput bundled resource imaging system (HUBRIS) as an extension to the Philips Research imaging development environment (PRIDE). HUBRIS enables PACS-connected medical imaging equipment to invoke tools provided by the Java Imaging Science Toolkit (JIST) so that a medical imaging platform (e.g., a magnetic resonance imaging scanner) can pass images and parameters to a server, which communicates with a grid computing facility to invoke the selected algorithms. Generated images are passed back to the server and subsequently to the imaging platform from which the images can be sent to a PACS. JIST makes use of an open application program interface layer so that research technologies can be implemented in any language capable of communicating through a system shell environment (e.g., Matlab, Java, C/C++, Perl, LISP, etc.). As demonstrated in this proof-of-concept approach, HUBRIS enables evaluation and analysis of emerging technologies within well-developed PACS systems with minimal adaptation of research software, which simplifies evaluation of new technologies in clinical research and provides a more convenient use of PACS technology by imaging scientists.

7967-14, Session 3

Viability of sharing MEG data using minimum-norm imaging

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Magnetoencephalography (MEG) measures magnetic fields ensuing from cerebral currents. Cortical activation maps estimated from MEG data have variability across subjects, trials, runs, and MEG centers. To combine MEG results across sites, we must demonstrate that inter-site variability in activation maps is not considerably higher than the other sources of variability. By demonstrating relatively low inter-site variability with respect to inter-run variability, we establish a statistical foundation for sharing MEG data across sites for more powerful group studies or clinical trials of pathology. In this work, we analyze whether pooling MEG data across sites is more variable than aggregating MEG data across runs when estimating significant cortical activity. We use data from left median nerve stimulation experiments in 4 subjects at each of 3 sites on 2 runs, occurring on consecutive days for each site. We estimate cortical current densities via minimum-norm imaging. Then, we compare maps across machines and across runs using two metrics: the Simpson coefficient, which admits equality if one map is equal in location to the other, and the Dice coefficient, which admits equality if one map is equal in location and size to the other. We determine if the mean similarity coefficient between sites is statistically equal to the mean similarity coefficient between runs at one site. We find the parameters necessary to share MEG data across national sites without noticeably affecting group

variation in significant activity, forming the basis for MEG data sharing globally.

7967-15, Session 3

Mobile medical image retrieval

S. Duc, A. Depeursinge, I. Eggel, H. Müller, HES-SO Valais (Switzerland)

Images are an integral part of medical routine and image retrieval has gained in importance mainly as a research domain in past years. Both textual and visual retrieval of images are essential. In the process of mobile devices becoming reliable and having a functionality of formerly fixed clients, mobile computing has gained ground and many applications have been explored. This creates a new field of mobile information access and in this context images can play an important role as they often allow to understand complex scenarios much quicker. This article describes constraints of an information retrieval system including visual and textual information retrieval from the medical literature of BioMedCentral.

Solutions for mobile data access on an iPhone in a web-based environment are presented as iPhones are frequently used. A web-based scenario was chosen to allow for a use by other smart phone platforms as well. Constraints of small screen and navigation with touch screen are taken into account in the development of the application. Mobile information access and particular access to images can be surprisingly efficient and effective. Images can be read on screen much faster and relevance of documents is can be identified quickly through the use of images contained in the text.

Problems with the many often incompatible mobile platforms were discovered and are listed in the text.

Mobile information access is a quickly growing domain and the constraints of mobile access also need to be taken into account for image retrieval.

7967-16, Session 4

Evaluation of a stand-alone computer-aided detection system for acute intra-cranial hemorrhage in emergency environments

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Acute intra-cranial hemorrhage (AIH) may result from traumatic brain injury (TBI). Successful management of AIH depends heavily on the speed and accuracy of diagnosis. Timely diagnosis in emergency environments in both civilian and military settings is difficult primarily due to severe time restraints and lack of resources. Often, diagnosis is performed by emergency physicians rather than trained radiologists. As a result, added support in the form of computer-aided detection (CAD) would greatly enhance the decision-making process and help in providing faster and more accurate diagnosis of AIH. This paper discusses the implementation of a CAD system in an emergency environment, and its efficacy in aiding in the detection of AIH.

7967-17, Session 4

DICOM-based computer-aided evaluation of intensity modulated radiotherapy (IMRT) treatment plans

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Intensity-modulated radiation therapy (IMRT) has gained popularity in the treatment of cancers because of its excellent local control with decreased normal tissue effects. Yet, computer planning for the treatment rely heavily on human inspection of resultant radiation dose distribution within the irradiated region of the body. Even for experienced planners, comparison of IMRT plans is definitely cumbersome and not error-free. To solve this problem, a computer-aided decision-support system was built for automatic evaluation of IMRT plans based on the DICOM standard. A DICOM-based IMRT plan with DICOM and DICOM-RT objects including CT scans, RT Structure Set, RT Dose and RT Plan were retrieved from the Treatment Planning System for programming. Utilizing the MATLAB program language, the decoding-encoding software applications were developed on the basis of the DICOM information object definitions. After tracing the clinical workflow and understanding the needs and expectations from radiation oncologists, a set of routines were written to parse key data items such as isodose curves, region of interests, dose-volume histogram from the DICOM-RT objects. Then six graphical user interfaces (GUIs) were created to allow planners to query for parameters such as overdose or underdose areas. A total of 30 IMRT plans were collected in a Department of Clinical Oncology for systematic testing of the DICOM-based decision-support system. Both structural and functional tests were implemented as a major step on the road to software maturity. With promising test results, this decision-support system could represent a major breakthrough in the routine IMRT planning workflow.

7967-18, Session 4

A multimedia ePR system to improve decision support in rehabilitation and performance through clinical gait and movement analysis

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Clinical decisions for improving motor function in patients both with disability as well as improving an athlete's performance are made through clinical gait and movement analysis. Currently, this analysis facilitates identifying abnormalities in a patient's motor function for a large amount of neuro-musculoskeletal pathologies. However definitively identifying the underlying cause or long-term consequences of a specific abnormality in the patient's movement pattern is difficult since this requires information from multiple sources and formats across different times and currently relies on the experience and intuition of the expert clinician. In addition, this data must be persistent for longitudinal outcomes studies. Therefore a multi-media ePR system integrating imaging informatics data could have a significant impact on decision support within this clinical workflow. We present the design and architecture of such an ePR system as well as the data types that need integration in order to develop relevant decision support tools. Specifically, we will present two data model examples: 1) A performance improvement project involving volleyball athletes and 2) Wheelchair propulsion evaluation of patients with disabilities. The end result is a new frontier area of imaging informatics research within rehabilitation engineering and biomechanics.

7967-19, Session 4

Evaluation of an automatic multiple sclerosis lesion quantification tool in an informatics-based MS e-folder system

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Multiple sclerosis (MS) is a demyelinating disease of the central nervous system. The chronic nature of MS necessitates multiple MRI studies to track disease progression. We have presented an imaging informatics decision-support system, called MS eFolder, designed to integrate

patient clinical data with MR images and a computer-aided detection (CAD) component for automatic white matter lesion quantification. The purpose of the MS eFolder is to comprehensively present MS patient data for clinicians and radiologists, while providing a lesion quantification tool that can be objective and consistent for MS tracking in longitudinal studies. The MS CAD algorithm is based on the K-nearest neighbor (KNN) principles and has been integrated within the eFolder system. Currently, the system has been completed and the CAD algorithm for quantifying MS lesions has undergone the expert evaluation in order to validate system performance and accuracy. The evaluation methodology has been developed and the data has been collected, including over 100 MS MRI cases with various age and ethnic backgrounds. The preliminary results of the evaluation are expected to include sensitivity and specificity of lesion and non-lesion voxels in the white matter, the effectiveness of different probability thresholds for each voxel, and comparison between CAD quantification results and radiologists' manual readings. The results aim to show the effectiveness of a MS lesion CAD system to be used in a clinical setting, as well as a step closer to full clinical implementation of the eFolder system.

7967-20, Session 5

The role of GPU computing in medical image analysis and visualization

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Description of purpose

The increasing size of data sets produced by multi-detector CT scanners has resulted in scans that are an order of magnitude large than a decade ago. This has created a new imaging paradigm which focuses on the volumetric nature of data. This shift represents an opportunity for a redefinition of how studies are viewed, processed, and analyzed.

Method(s)

The focus of the session will be potential utilization of CUDA and OpenCL in medical imaging software. Existing algorithms will be discussed in the context of run time acceleration using GPU computing models. The topics include 3D visualization which includes volumetric segmentation, display, and data manipulation. In addition, several back-end preprocessing algorithms will be discussed including bone extraction algorithms, lumen tracking, and organ segmentation.

Results

Several algorithms will be dissected in detail including accelerating 3D image manipulation, modified rigid registration, wireframe deformation, and lumen tracking. There will be extended discussion of how computer vision problems specific to medical imaging can be framed in a massively parallel context. The relative merits of CPU vs. GPU approaches to these segmentation algorithms will be discussed.

Conclusions

To a clinical radiologist, the large data sets in modern medical imaging studies are simultaneously beneficial in their elucidation of anatomic detail and detrimental in the time necessary to view and process the images. The next generation of medical imaging software will need to incorporate massively parallel computing paradigms in order to keep pace with the advances in spatial resolution on the hardware side.

7967-21, Session 5

Open source tools for standardized privacy protection of medical images

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Objective: A secondary use of medical images can provide important information for research projects and community healthcare networks. Patient privacy becomes an issue in such scenarios since the disclosure of personal health information (PHI) has to be prohibited in a sharing environment. In the absence of appropriate tools for privacy preservation, personal data is often processed on a case by case basis. In general, most PHI should be completely removed from the images according to the respective privacy regulations, but some basic and alleviated data is usually required for accurate image interpretation. DICOM already provides defined mechanisms for standardized anonymization. Our objective is to utilize and enhance these specifications in order to provide reliable software implementations for de- and re-identification of medical images suitable for online and offline delivery.

Methods: DICOM (Digital Imaging and Communications in Medicine) images are de-identified by replacing PHI-specific information with values still being reasonable for imaging diagnosis and patient indexing. If desired, the original data is kept (asymmetrically) encrypted in the image object, thus permitting later re-identification. Also, the software offers means for standardized encryption and decryption of complete medical image objects as well as DICOM conformant media encryption for offline transport. The approach is evaluated by a prototype based on the open source framework DCMTK (DICOM Toolkit) utilizing standardized de- and re-identification mechanisms.

Results: The developed tools successfully de-identify and re-identify DICOM images. They are evaluated in a German expert network in the area of skeletal dysplasia, SKELNET, but can also be applied to related projects.

Conclusions: A set of tools has been developed for DICOM de-identification that meets privacy requirements of both offline and online sharing environments and fully relies on standard-based methods.

7967-22, Session 5

2D versus 3D mammography observer study

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Mammography is a screening tool used to aid in the early detection of breast cancer. Mammography has progressed from film-screen to digital imaging. However, 2D digital imaging has the diagnostic limitation of overlapping tissues due to the nature of 2D projections. As the next step, 3D imaging holds promise to overcome the problem of overlapping tissues, especially in dense breasts, thereby improving detection outcomes. The 3D mammography technique presented in this paper aims to overcome such limitations which includes a specialized digital mammography unit paired with an innovative 3D display system. In order to evaluate this new 3D technology, an observer study using a mammography phantom was performed to compare traditional 2D mammography with this new 3D mammography technique.

7967-23, Session 5

Efficient access to compressed 3D and 4D MRI using JPEG2000

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Modern Medical diagnoses are more and more based upon interactivity with different kinds of data. Images are at the very base of these diagnosis policies and require high degrees of interaction, a requirement that most compression standards do not meet since for achieving this, high granularity levels are needed. JPEG2000 (J2K) has lately arisen as a compression standard that tackles with these challenges, allowing appropriate compression rates and efficient access to data, i.e. random spatial access at any resolution and with any desired quality. Based on the J2K standard method, this article presents a 3D compression method which adapts the J2K simplicity handling of 2D data and includes the 3D information with no modification of the structures used in 2D implementations. The proposed method was compared with an ordinary J2K implementation in 2D, using 3D and 4D data, showing that the

3D strategy saved a 14,6 %.hard disk space when compared with the conventional 2D.

7967-24, Session 6

IHE for surgery: scope and first proposals for a new domain within the 'integrating the healthcare enterprise' initiative

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The current trend in medical device industry towards modular systems architectures leads to a growing need of standards which guarantee interoperability between modules and systems. Unfortunately, there are several standards as well as proprietary solutions which might have an overlapping scope, and within standards there are sometimes different interpretations on how a standard shall be used.

We propose to use the "Integrating the Healthcare Enterprise (IHE)" initiative as a platform for coordinating the use of standards for the surgical domain. To show the feasibility of this approach, we sketched three Integration Profiles within the field of implantation planning: One for the description of surface meshes, one for Implant Templates and one for Implantation Plans. The Integration Profiles are describing, how the corresponding DICOM data structures introduced by DICOM Supplements 131, 132 and 134 (Implant Template, Surface Mesh Segmentation and Implantation Plan) shall be used in order to accomplish the data transfer needed for the whole process chain from implant manufacturer via the manufacturer of an implantation planning software to the end user in the hospital.

This is the first proposal for IHE profiles for the surgical domain. The profiles could be the basis of a new domain "Surgery" within IHE.

7967-25, Session 6

XDS in healthcare, could it lead to a duplication problem?: empirical study from VGR Sweden

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Managing different registries and repositories within healthcare regions grows the risk of duplication storage of information. This is due to the fact that when a medical decision is made often a local copy of the regional information needs to be saved for legal or documentation purposes. The information needs to be easy accessible, making the background for the medical decision transparent. In the Region Västra Götaland, Sweden, data is shared from 29 X-ray departments with different PACS and RIS systems through the Infobroker solution. Text from EPR systems are stored as DICOM-Structured Reports objects, together with the images. Interoperability is implemented and slowly taken into use based on the IHE mission, e.g. XDS-I registry and central repository. The VGR strategy was to apply one regional XDS registry and repository instead of many local registries and repositories. Resulting in an information system vendor independence and to mineralization of data duplication. On top of the regional storage is a copy of local production stored for approximately three months. Occasionally, when central data is transferred from the regional repository to the local system it is also stored locally, creating 5-6 % duplication of data.

To the best of our knowledge no other regional XDS registry and repository, including both images and texts from multiple RIS and PACS vendors, have been implemented globally elsewhere. Effective ways of sharing medical images and texts through regional XDS registries and repositories could lead to new ways of carrying out work.

7967-26, Session 6

Design of image sharing and exchanging for cross-enterprise and cross-domain collaborative healthcare in Shanghai

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Purpose: Shanghai is large city with about 20 million residents. There are about 500 hospitals and clinics being distributed in more than 20 districts and hospital groups (called domains), which provide healthcare services to the residents and citizens. With the city quick developing, the contradiction between the demanding and providing of healthcare resources is becoming serious, since more and more residents live far away from city center, but most large hospitals are still staying in the city center areas. So, the government wants to solve the problems by encouraging patient going to small hospitals first to have preliminary diagnosis such as having imaging examination and let senior radiologists, working in large hospitals, to make final imaging diagnosis through regional healthcare information exchanging platform. Also the government wants to develop image-enabled EHR (Electronic Healthcare Record) sharing mechanism between some of hospitals to reduce the costs by re-using the prior examination data obtained in other hospitals. In this presentation, we present a design method and preliminary evaluation of image sharing for Cross-Enterprise and Cross-Domain Collaborative Healthcare in Shanghai.

7967-27, Session 6

Design and evaluation of web-based image transmission and display with different protocols

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There are many Web-based image accessing technologies used in medical imaging area, such as component-based (ActiveX Control) thick client Web display, Zerofootprint thin client Web viewer (or called server side processing Web viewer), or Flash Rich Internet Application(RIA) based Web display. Different Web display methods have different peformance in different network environment. In this presenation, we give an evaluation on two developed Web based image display middleware systems. The first one is used for thin client Web display. It works between a PACS Web server with WADO interface and thin client. The PACS Web server providesJPEG format images to the Web display middleware, which transfers the JPEG images to a thin client running javascript or Flash Rich Internet Application(RIA). The second one is for thick client Web display. It works between a PACS Web server with WADO interface and thick client running Internet Explore broswer containing ActiveX plugin or Flash RIA program.

7967-28, Session 6

Integration of DICOM and openEHR standards

Y. Wang, Tongji Univ. (China); Z. Yao, Shanghai Institute of Biological Sciences (China); L. Liu, Shanghai Ctr. for BioInformation Technology (China)

The standard format for medical imaging storage and transmission is Digital Imaging and Communications in Medicine (DICOM). openEHR is an open standard specification in health informatics that describes the management and storage, retrieval and exchange of health data in electronic health records. Considering that the integration of DICOM and openEHR is beneficial to information sharing, on the basis of XML-based DICOM format, we developed a method of creating a DCM-Archetype in openEHR to enable the integration of DICOM and openEHR.

Each DICOM file contains abundant imaging information. However, because reading a DICOM involves looking up the DICOM Data Dictionary, the readability of a DICOM file has been limited. openEHR has creatively adopted two level modeling method, making clinical information divided into lower level, the information model, and upper level, archetypes and templates. But one critical challenge posed to the development of openEHR is the information sharing problem, especially in imaging information sharing. For example, some important imaging information cannot be displayed in an openEHR file. In this paper, to enhance the readability of a DICOM file and semantic interoperability of an openEHR file, on the basis of XML-based DICOM format, we developed a method of mapping a DICOM file to an openEHR file by adopting the form of archetype defined in openEHR. Because an archetype has a tree structure, after mapping a DICOM file to an openEHR file, the converted information is structuralized in conformance with openEHR format. This method enables the integration of DICOM and openEHR and data exchange without losing imaging information between two standards.

7967-29, Session 6

DICOM involving XML Path-Tag

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Digital Imaging and Communications in Medicine (DICOM) is a standard for handling, storing, printing, and transmitting information in medical imaging. XML (Extensible Markup Language) is a set of rules for encoding documents in machine-readable form which has become more and more popular. The combination of these two is very necessary and promising. Using XML tags instead of numeric labels in DICOM files will effectively increase the readability and enhance the clear hierarchical structure of DICOM files. However, due to the fact that the XML tags rely heavily on the orders of the tags, the strong data dependency has a lot of influence on the flexibility of inserting and exchanging data. In order to improve the extensibility and sharing of DICOM files, this paper introduces XML Path-Tag to DICOM. When a DICOM file is converted to XML format, adding simple Path-Tag into the DICOM file in place of complex tags will keep the flexibility of a DICOM file while inserting data elements and give full play to the advantages of the structure and readability of an XML file. Our method can solve the weak readability problem of DICOM files and the tedious work of inserting data into an XML file. In addition, we set up a conversion engine that can transform among traditional DICOM files, XML-DCM and XML-DCM files involving XML Path-Tag efficiently.

Conference 7968: Ultrasonic Imaging, Tomography, and Therapy

Sunday-Monday 13-14 February 2011 • Part of Proceedings of SPIE Vol. 7968 Medical Imaging 2011: Ultrasonic Imaging, Tomography, and Therapy

7968-01, Session 1

Double difference tomography for breast ultrasound sound speed imaging

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Breast ultrasound tomography is a rapidly developing imaging modality that has the potential to impact breast cancer screening and diagnosis. Double-difference (DD) tomography utilizes more accurate differential time-of-flight (TOF) data to invert the sound speed structure of the breast. It can produce more precise and better resolution breast sound speed images than standard tomography that uses absolute TOF data. We apply DD tomography to phantom data and excised mouse data. DD tomograms demonstrate sharper sound speed contrast than the standard tomograms.

7968-02, Session 1

Evaluation of the Bresenham algorithm for image reconstruction with ultrasound computer tomography

N. Spiess, M. Zapf, N. V. Ruiter, Karlsruher Institut für Technologie (Germany)

At Karlsruhe Institute of Technology an Ultrasound Computer Tomography system (USCT) is under development for early breast cancer detection. With 3.5 millions of acquired raw data sets and up to one billion voxels for an image, the reconstruction of breast volumes may last weeks in highest possible resolution. The currently applied backprojection algorithm, synthetic aperture focusing technique (SAFT), offers only limited potential to further decrease the reconstruction time. An alternative to the backprojection is to rasterize the backprojected ellipsoids A well known rasterization algorithm is the Bresenham algorithm, which was originally designed to rasterize lines. In this work the existing Bresenham concept to rasterize circles is extended to comply with the requirements of image reconstruction in USCT: The circle rasterization was adapted to rasterize spheres and was extended to floating point parameterization. The evaluation of the algorithm showed that the quality of the rasterization is comparable to the original algorithm. The achieved performance of the algorithm was 12 MVoxel/sec for the circle rasterization and 3.5 MVoxel/sec for the sphere rasterization, resulting in an initial acceleration of the reconstruction of up to the factor of two For future work the presented rasterization algorithm offers great potential for further speed up.

7968-03, Session 1

Modification of Kirchhoff migration with variable sound speed and attenuation for tomographic imaging of the breast

S. P. Schmidt, O. Roy, C. Li, N. Duric, Karmanos Cancer Institute (United States); Z. Huang, Wayne State Univ. (United States)

Conventional ultrasound techniques use beam-formed, constant sound speed ray models for fast image reconstruction. However, these techniques are inadequate for the emerging new field of ultrasound tomography (UST). We present a new technique for reconstruction of reflection images from UST data. We extend the planar Kirchhoff migration method used in geophysics and combine it with sound speed and attenuation data obtained from the transmission signals to create reflection ultrasound images that are corrected for refractive and attenuative effects. The resulting technique is applied to in-vivo breast data obtained with an experimental prototype. The results indicate that sound speed and attenuation corrections lead to considerable improvements in image quality, particularly in dense tissues where the refractive and scattering effects are the greatest.

7968-04, Session 1

Realization of an optimized 3D USCT

N. V. Ruiter, G. Göbel, L. Berger, M. Zapf, H. Gemmeke, Karlsruher Institut für Technologie (Germany)

A promising candidate for improved imaging of breast cancer is ultrasound computer tomography (USCT). Current experimental USCT systems are still focused in elevation dimension resulting in a large slice thickness, limited depth of field, loss of out-of-plane reflections, and a large number of movement steps to acquire a stack of images. 3D USCT emitting and receiving spherical wave fronts overcomes these limitations. We built an optimized 3D USCT with nearly isotropic 3D PSF, realizing for the first time the full benefits of a 3D system. The 3D USCT II consists of a semi-ellipsoidal transducer holder cut from polyoxymethylene. Grouped into transducer array systems with embedded amplifiers and emitter electronics, 2041 transducers are mounted in the holder. The data acquisition is carried out with 480 parallel channels at 20 MHz and 12 Bit. The device can be rotated and translated. 3.7 million A-Scans with 20 GByte of raw data are acquired for one breast volume. The aperture is implemented together with water supply, disinfection unit, temperature control, and movement mechanics in a patient bed. With data acquisition time of less than two minutes for one breast volume, the new system enables the next step of our research: a first clinical study.

7968-05, Session 1

Robust array calibration using time delays with application to ultrasound tomography

O. Roy, Karmanos Cancer Institute (United States); I. Jovanovic, Ecole Polytechnique Fédérale de Lausanne (Switzerland); N. Duric, Karmanos Cancer Institute (United States); L. Poulo, Analogic Corp. (United States); M. Vetterli, Ecole Polytechnique Fédérale de Lausanne (Switzerland)

Accurate calibration is a requirement of many array signal processing techniques. We investigate the calibration of a transducer array using time delays. A strategy based on the mean square error criterion is derived and the interpolation of missing measurements is discussed. The proposed method is made robust to noise and model mismatch by means of a novel iterative technique for distance matrix denoising. The convergence of the method is proved. Finally, the accuracy of the proposed calibration algorithm is assessed using experimental data obtained from an ultrasound scanner designed for breast cancer detection.

7968-06, Session 2

The development of a combined b-mode, ARFI, and spectral Doppler ultrasound imaging system for investigating cardiovascular stiffness and hemodynamics

J. R. Doherty, D. M. Dumont, G. E. Trahey, Duke Univ. (United States)

The progression of atherosclerotic disease, caused by the formation of plaques within arteries, is a complex process believed to be a function of the localized mechanical properties of the arterial wall and the hemodynamic loading on that wall. It is hypothesized that measurements of wall-shear rate (WSR) and wall-shear stress (WSS) may provide important information regarding the growth of soft lipid filled plaques believed to be more vulnerable to causing stroke compared with harder calcified plaque regions. With the ability to identify soft plaques and regions of potential plaque growth, a clinician could better diagnose a patient's risk of stroke and the expected benefit from endarterectomy surgery or medical intervention.

To that end, the approach taken in this work was to combine conventional B-mode with Acoustic Radiation Force Impulse (ARFI) imaging and spectral Doppler into a single imaging system capable of simultaneously measuring the tissue displacements and WSR throughout the cardiac cycle and over several heartbeats. Implemented on a conventional scanner, the carotid arteries of human and canine subjects were scanned to demonstrate the initial in vivo feasibility of the method.

ARFI data provided high resolution images of vessel and intima layer boundaries, while spectral Doppler data provided highly sampled blood velocity profiles. Temporal sequences of ARFI images showed consistent tissue displacements while spectral Doppler images showed cyclic variations in the velocity profiles and corresponding WSR throughout the cardiac cycle. Excellent correspondence was observed between B-mode, ARFI, and spectral Doppler data with matched ECG data from beat-to-beat.

7968-07, Session 2

Single pulse frequency compounding protocol for superharmonic imaging

M. G. Danilouchkine, P. van Neer, G. Matte, Erasmus MC (Netherlands); M. Verweij, Technische Univ. Delft (Netherlands); N. de Jong, Erasmus MC (Netherlands)

Second harmonic imaging is currently adopted as a commercial standard in echographic systems. A new imaging, coined as superharmonic imaging (SHI), combines the 3rd-5th harmonics also stemming from nonlinear sound propagation. The new imaging technique could further enhance resolution and quality of echographic images. To meet the bandwidth requirement for SHI a dedicated phased array has been developed: a low frequency subarray, intended for transmission, interleaved with a high frequency subarray, used in reception. As the bandwidth of the high frequency elements is limited, the gaps in between the harmonics in the spectral domain cause multiple reflection artifacts. Recently, we introduce a dual-pulse frequency compounding method to suppress those artifacts at a price of a reduced frame rate. In this study we investigate the feasibility of performing the frequency compounding protocol in a single shot.

7968-08, Session 2

A novel imaging technique based on the spatial coherence of backscattered waves: demonstration in the presence of acoustical clutter

J. J. Dahl, Duke Univ. (United States); G. F. Pinton, Ecole Supérieure de Physique et de Chimie Industrielles (France); M. A. Lediju, G. E. Trahey, Duke Univ. (United States)

In the last 20 years, the number of suboptimal and inadequate ultrasound exams has increased. This trend has been linked to the increasing population of overweight and obese individuals. The primary causes of image degradation in these individuals are often attributed to phase aberration and clutter. Phase aberration degrades image quality by distorting the transmitted and received pressure waves, while clutter degrades image quality by introducing incoherent acoustical interference into the received pressure wavefront.

Although significant research efforts have pursued the correction of image degradation due to phase aberration, few efforts have characterized or corrected image degradation due to clutter.

We have developed a novel imaging technique that is capable of differentiating ultrasonic signals corrupted by acoustical interference. The technique, named short-lag spatial coherence (SLSC) imaging, is based on the spatial coherence of the received ultrasonic wavefront at small spatial distances across the transducer aperture.

We demonstrate comparative B-mode and SLSC images using full-wave simulations that include the effects of clutter and show that SLSC imaging generates contrast-to-noise ratios (CNR) and signal-to-noise ratios (SNR) that are significantly better than B-mode imaging under noise-free conditions. In the presence of noise, SLSC imaging significantly outperforms conventional B-mode imaging in all image quality metrics. We demonstrate the use of SLSC imaging in vivo and compare B-mode and SLSC images of human thyroid and liver.

7968-09, Session 2

Using high-power light emitting diodes for photoacoustic imaging

R. S. Hansen, Univ. of Southern Denmark (Denmark)

Photoacoustic imaging will become an important supplement to conventional ultrasound imaging. However, the equipment needed is still too delicate to bring this technique into the daily clinical work. The pulsed light source is the area of interest in the present report. Usually, large and costly laser systems are used to provide high-energy light pulses with a chosen wavelength. Pulsed semiconductor lasers have been demonstrated as a possible alternative light source for the photoacoustic imaging purpose. As an alternative to laser sources, the preliminary result of using a pulsed high-power light emitting diode, LED, for photoacoustic imaging is presented here. The pulsed light source is created from a Luxeon LXHL_PD09 red LED (250mW optical output power at 1 Amp current). The LED is supplied with current pulses 60ns wide and 40A peak. The LED delivers 60ns light pulses with approximately 6W peak power. The phantom used consists of a thin stripe (3mm high x 5mm wide) of green colored gelatine overlaid by a 3cm layer of colorless gelatine. The light pulses from the LED are collected by a lens system and focused on the green gelatine from beneath the sample. The acoustic response from the green gelatine is detected with a single focused transducer on the upper surface of the 3cm thick colorless gelatine layer. The response is clearly observed when the measurement is taken as an average of 50,000 pulses. Is it concluded that despite the relatively low pulse power, for some purposes, a combination of of LED's could be a candidate for an inexpensive light source.

7968-10, Session 2

Photoacoustic tomography with integrating fiber-based annular detectors

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Photoacoustic Tomography (PAT) is an emerging imaging modality combining the advantages of optical imaging (high contrast) and ultrasonic imaging (high spatial resolution). Applications for PAT are mainly in imaging soft tissue. For photoacoustic imaging the sample is illuminated by a short pulse of electromagnetic energy. Depending on the specific absorption rate (SAR) the electromagnetic radiation is absorbed and the subsequent thermoelastic expansion launches broadband ultrasonic waves. Usually point-like piezo detectors are used to measure the ultrasonic waves. Our group introduced integrating detectors a few years ago. This type of detector integrates the pressure at least along one dimension. Integrating line detectors, for example, can be realized by using either free-beam or fiber-based interferometers. The latter approach also allows more sophisticated detector geometries. We present a fiber-based annular detector for tomography. Thereby the sample is rotated inside the annular detector on a position different from the axis of symmetry of the annular detector. By moving the detector along the axis of the ring one acquires enough data for a subsequent 3D image reconstruction. Therefore, a tomography can be performed with just one rotation axis and one linear axis. For image reconstruction a novel algorithm has been derived that has been tested on simulated data. Here we report on an imaging setup using such a fiber-based annular detector. Measurements of simple objects and subsequent image reconstruction from real data are shown for the first time.

7968-11, Session 2

Development of a c-scan photoacoutsic imaging probe for prostate cancer detection

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Prostate cancer is the second leading cause of death in American men after lung cancer. The current screening procedures include Digital Rectal Exam (DRE) and Prostate Specific Antigen (PSA) test, along with Transrectal Ultrasound (TRUS). All suffer from low sensitivity and specificity in detecting prostate cancer in early stages. There is a desperate need for a new imaging modality. We are developing a prototype transrectal photoacoustic imaging probe to detect prostate malignancies in vivo that promises high sensitivity and specificity. To generate photoacoustic (PA) signals, the probe utilizes a high energy 1064 nm laser that delivers light pulses onto the prostate at 10Hz with 10ns duration through a fiber optic cable. The designed system will generate focused C-scan planar images using acoustic lens technology. A 5 MHz custom fabricated ultrasound sensor array located in the image plane acquires the focused PA signals, eliminating the need for any synthetic aperture focusing. The lens and sensor array design was optimized towards this objective. For fast acquisition times, a custom built 16 channel simultaneous backend electronics PCB has been developed. It consists of a low-noise variable gain amplifier and a 16 channel ADC. Due to the unavailability of 2d ultrasound arrays, in the current implementation several B-scan (depth-resolved) data is first acquired by scanning a 1d array, which is then processed to reconstruct either 3d volumetric images or several C-scan planar images. Experimental results on phantoms will be presented to demonstrate the system capability in terms of resolution and sensitivity.

7968-12, Session 3

Support-vector-machine-based classification of multidimensionnal signals for fetal activity characterization

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Electronic fetal monitoring may be required during the whole pregnancy to closely monitor certain fetal and maternal disorders. Currently used methods suffer from many limitations and are not sufficient to evaluate fetal suffering. Fetal activity parameters such as movements, heart rate and the associated parameters are essential indicators of the fetal well being, and no device gives a simultaneous access and a sufficient estimation of all these parameters to evaluate the fetus health.

We built a multi-transducer-multi-gate Doppler system with dedicated signal processing techniques for fetal activity parameters extraction in order to detect fetus's suffering. To achieve this goal, a data consisting of a two groups of fetal signals (normal and pathological) has been established and provided by physicians. From estimated parameters an instantaneous Manning-like score, referred to as ultrasonic score was introduced, and was used together with movements, heart rate and the associated parameters in a classification process using Support Vector Machines (SVM) method.

The goal of SVM is to find the optimal separating hyperplane with the largest margin which is induced from a training data set, and produce a classifier with high generalization ability and a low classification error. We studied influence of the variables and evaluated the performance of the SVM using the computation of sensibility, specificity, percentage of support vectors and total classification accuracy. We showed our ability to separate the data into two sets : normal fetuses and pathological fetuses and obtained an excellent matching with the clinical classification performed by physician.

7968-13, Session 3

An expectation maximization framework for an improved tissue characterization using ultrasounds

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Tissue characterization through ultrasounds is an intensive research area. This procedure is generally based on the analysis of the echo signal. As the ultrasound echo is degraded by the system PSF, deconvolution could be employed to provide a tissue response estimate, exploitable for a better characterization.

Standard deconvolution techniques pursue a visual quality improvement only and hence exploit simplified models of the tissue reflectivity: Gaussian or Laplacian prevalently. Their solutions are badly biased by these assumptions and unsuitable for classification purposes. Hereto, we developed a novel deconvolution framework, expressively designed for an improved tissue characterization.

We model tissue reflectivity with a non-standard Generalized Gaussian Distribution. Thanks to its shape parameter, this distribution lets sequences of arbitrary sparsity to be generated, providing adequate representations to the most general tissue structures. Deconvolution is then formalized as a Maximum a Posteriori estimate, in which the tissue response is restored along with the associated shape parameter. Correspondingly, the restored solutions properly reflect the fundamental structural properties of the true tissue, and undesired biasing effects are avoided.

The framework was evaluated on phantom data, realized as Orgasol solutions with six different concentrations, ranging from 0.25% to 24%. We adopted a four-features approach and a Support Vector Machine classifier. When up to four classes were considered, classification accuracy improved of roughly 10% after deconvolution; this rate increased to a remarkable 20% when more classes were involved. Standard Wiener filtering and l1-norm constraint were also considered for comparison and no noticeable improvements were obtained in these cases.

7968-15, Session 3

Computer-aided tissue characterization using ultrasound-induced thermal effects: analytical formulation and in vitro animal study

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Ultrasound radio-frequency (RF) time series analysis provides an effective tissue characterization method to differentiate between healthy and cancerous prostate tissues, but the physical processes underlying this tissue typing analysis were not understood. In this paper, an analytical model is presented that describes the variations in tissue microanatomy that accompany ultrasound RF time series acquisition procedures. These ultrasound-induced effects, which depend on tissue mechanical and thermophysical properties, are hypothesized to be the major contributor to the tissue typing capabilities of the RF time series analysis. The model is used to derive two novel tissue characterization features. The two features are used with a support vector machine classifier to characterize three animal tissue types: chicken breast, bovine liver, and bovine steak. Accuracy values greater than 90% are achieved when the bovine steak tissue is differentiated from the chicken breast and bovine liver tissues. Moreover, the proposed features differentiate the chicken breast tissue from the bovine liver tissue with an accuracy of 79.5%. The proposed model provides a framework to optimize the ultrasound RF time series analysis for future clinical procedures.

7968-16, Session 3

Three-dimensional computer simulation of high-frequency ultrasound imaging of healthy and cancerous murine liver tissues

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Substantial progress has been made towards using high-frequency (20-60 MHz) ultrasound to track tumor growth in preclinical cancer models; however, correlation of high-frequency backscattering to tissue microanatomy is an incompletely understood problem. In this paper, a histology-based simulation framework is presented to relate high-frequency backscattering to tissue microanatomy. The software employs a three-dimensional (3-D) microanatomical model that treats tissue as a population of nuclei embedded in a homogeneous cytoplasm to create simulated healthy tissue and simulated tumor that match the nuclei number density, sizes of nuclei, and spatial arrangement of nuclei of a healthy mouse liver and an experimental liver metastasis. A parallel first-order k-space method is used to synthesize B-mode images by computing linear 3-D propagation of focused 40-MHz pulses in the simulated tissues. Gray-level histograms with 13 bins evenly spaced over 256 gray levels are constructed for the simulated images and compared with histograms of corresponding experimental images. The histogram of the simulated healthy tissue matches the histogram of the healthy liver within one standard deviation in all 13 bins when the sound speed and mass density of the nuclei are set to 1503 m/s and 1430 kg/m^3. Simulated and experimental speckle distributions for the liver metastasis match in 11 of 13 bins when the sound speed and density of the nuclei are set to 1527 m/s and 1140.5 kg/m^3. The simulations suggest that variations in first-order speckle statistics between healthy and cancerous murine liver tissues reflect changes in both tissue acoustic and structural properties.

7968-17, Session 4

Automatic detection and estimation of biparietal diameter from fetal ultrasonography

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Fetal biparietal diameter (BPD) is known to provide a reliable estimate of gestational age (GA) of a fetus in the first half of pregnancy. In this paper, we present an automated method to identify and measure BPD from B-mode ultrasound images of fetal head. The method (a) automatically detects and places a region-of-interest on the head based on a prior work in our group (b) utilizes the concept of phase congruency for edge detection and (c) employs a cost function to identify the third ventricle inside the head (d) measures the BPD along the perpendicular bisector of occipital frontal diameter (OFD) from the outer rim of the cranium closer to the transducer to the inner rim of the cranium away from the transducer. The cost function is premised on the distribution of anatomical shape, size and presentation of the third ventricle in images that adhere to clinical guidelines describing the scan plane for BPD measurement. The OFD is assumed to lie along the third ventricle. The algorithm has been tested on 137 images acquired from four different scanners. Based on GA estimates and their bounds specified in Standard Obstetric Tables, the GA predictions from automated measurements are found to be within ±2SD of GA estimates from manual measurements by the operator and a second expert radiologist in 98% of the cases. The method described in this paper can also be adapted to assess the accuracy of the scan plane based on the presence/absence of the third ventricle.

7968-18, Session 4

A two dimensional locally regularized strain estimation technique: preliminary clinical results for the assessment of benign and malignant breast lesions

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We previously developed a 2D locally regularized strain estimation technique that was already validated with ex vivo tissues. In this study, our technique is assessed with in vivo data, by examining breast abnormalities in clinical conditions. Method reliability is analyzed as well as tissue strain fields according to the benign or malignant character of the lesion. Ultrasound RF data were acquired in two centers on ten lesions, five being classified as fibroadenomas, the other five being classified as malignant tumors, mainly ductal carcinomas from grades I to III. The estimation procedure we developed involves maximizing a similarity criterion (the normalized correlation coefficient or NCC) between pre- and post-compression images, the deformation effects being considered. The probability of correct strain estimation is higher if this coefficient is closer to 1.

Results demonstrated the ability of our technique to provide good-quality strain images with clinical data. For all lesions, movies of tissue strain during compression were obtained, with strains that can reach 15%. The NCC averaged over each movie was computed, leading for the ten cases to a mean value of 0.93, a minimum value of 0.87 and a

maximum value of 0.98. These high NCC values confirm the reliability of the strain estimation. Moreover, lesions were clearly identified for the ten cases investigated. Finally, we have observed with malignant lesions that compared to ultrasound data, strain images can put in relief a more important lesion size, and can help in evaluating the lesion invasive character.

7968-19, Session 4

Preliminary comparison between real-time in vivo spectral and transverse oscillation flow estimates

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Spectral estimation is considered the gold standard in medical ultrasound blood velocity estimation. Using transverse oscillation (TO) the flow angle and velocity can be calculated for every pixel within the range gate through the cardiac cycle.

The right common carotid arteries of three healthy volunteers were scanned longitudinally. Spectral and TO data were obtained simultaneously.

The mean TO angle and standard deviations were calculated for each volunteer {52(18);55(23);60(16)}°.

Angles for spectral estimation were obtained {52;56;52}°.

Mean TO velocity at peak systole (PS) {76(15);95(17);77(16)}cm/s and at end diastole (ED) {17(6);18(6);24(6)}cm/s were calculated. Spectral velocity estimates at PS {77;110;76}cm/s and ED {18;18;20}cm/s were obtained. The variance of the TO estimator at PS {153;132;57} and the physiological variance {62;77;40} were calculated.

Mean TO angle estimates agrees with the angle used for spectral estimation. TO velocity estimates agrees with the spectral estimates. The physiological variance is lower than the variance of the estimator.

From preliminary data it is indicated that TO angle estimation can replace the operator-dependent angle correction used for spectral velocity estimation. A larger population is needed to investigate if the variation of the temporal vector angle estimate is caused by the variation of the estimator. Real-time in vivo TO data provides detailed temporal and spatial vector estimates with diagnostic potential.

7968-20, Session 4

2D/3D image fusion of x-ray mammograms with speed of sound images: evaluation and visualization

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Breast cancer is the most common cancer among women. The most effective method for early detection is medical imaging. The established screening method to detect breast cancer is X-ray mammography. However, X-ray frequently provides poor contrast of tumors located within glandular tissue. In this case, additional modalities like MRI are used for diagnosis in clinical routine. A new imaging approach is Ultrasound Computer Tomography, generating three-dimensional speed of sound images. High speed of sound is expected to be an indicator of cancerous structures. Therefore, the combination of speed of sound images and X-ray mammograms may benefit early breast cancer diagnosis. In previous work, we proposed a method based on Finite Elements to automatically register speed of sound images with the according mammogram. The FEM simulation overcomes the challenge that X-ray mammograms show two-dimensional projections of a deformed breast whereas speed of sound images render a three-dimensional undeformed breast in prone position. For further evaluation of the registration quality, 15 datasets from a clinical study were used. The quality of registration was measured by the displacement of the center of a lesion marked in both modalities. We found a mean displacement of 7.1 mm. For visualization, an overlay technique was developed, which displays speed of sound information directly on the mammogram. Hence, the methodology provides a good basis for multimodal diagnosis with mammograms and speed of sound images. It proposes a guidance tool for radiologists who may benefit from the combined information.

7968-21, Session 4

Breast imaging with ultrasound tomography: a comparative study with MR

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Magnetic resonance (MR) imaging is currently recognized as the most accurate means for determining tumor involvement in breast tissue. However, this imaging modality is extremely costly to house and operate, requires a specialized staff, has relatively long scan times, and can be uncomfortable for the patient. Consequently, because such disadvantages have limited the use of MR in screening and diagnosis, a modality that can rival MR's image quality while obviating these difficulties has potential for a significant societal impact. A novel method, based on the principles of ultrasound tomography (UST),was used to generate in-vivo patient data and reconstruct images of the breast. This paper reports on a study that compares images taken with the UST method and MR.

The data were collected at the Karmanos Cancer Institute in Detroit, MI from patients recruited at our breast center. Tomographic sets of images were constructed from the data and used to form 3-D image stacks of sound speed, attenuation, and reflection parameters corresponding to the volume of the breast. The three image stacks were fused together using variable thresholds for multi-parameter visualization of breast tissue. From qualitative and quantitative assessments of both sets of images, we show that UST and MRI images show strikingly similar representations of a patient's breast anatomy. In addition, our ongoing study shows a generally high degree of correlation between the MR images and those obtained with UST when detecting suspicious lesions and defining tumor margins. Small differences in visualization of breast anatomy can be accounted for by differences in voxel characteristics and the fact that the breast positioning differs slightly between the UST and MR exams.

7968-22, Session 4

Relationship between breast sound speed and mammographic percent density

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Despite some shortcomings, mammography is currently the standard of care for breast cancer screening and diagnosis. However, breast ultrasound tomography (UST) is a rapidly developing imaging modality that has the potential to overcome some of the drawbacks of mammography. It is known that women with high breast densities have a greater risk of developing breast cancer. Measuring breast density is accomplished through the use of mammographic percent density, defined as the ratio of fibroglandular to total breast area. Our prototype uses ultrasound tomography to create sound speed images of the patient's breast. These images can be useful as a diagnostic aid because evidence suggests that the sound speed in a tissue is proportional to the physical density of the tissue. The purpose of this work is to

compare UST measurements of breast density with the measurement of mammographic percent density. A cohort of 251 patients was studied using both imaging modalities and the results suggest that the volume averaged breast sound speed is significantly related to mammographic percent density. The Spearman correlation coefficient was found to be 0.73 for the combined cohort of patients. Since sound speed measurements do not require ionizing radiation or physical compression, they have the potential to form the basis of a safe, potentially more accurate surrogate marker of breast density.

7968-23, Session 5

Finite element model of transducer array systems for 3D ultrasound computer tomography

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Breast cancer is the most common type of cancer for women in Europe and North America. The established standard screening method to detect tumors is X-ray mammography. However, X-ray mammography often has low contrast for tumors located within glandular tissue. A new approach is the 3D Ultrasound Computer Tomography (USCT), which is expected to detect small tumors at an early stage. This paper describes the development and the results of Finite Element Method (FEM) simulations of the Transducer Array System (TAS) used in our 3D USCT. As not all required material parameters were available, the main challenge of this work was to determine these values. After detailed analysis, a set of material parameters was identified which fit the measured data best. The quality of the simulation was evaluated by comparing the simulated impedance characteristics with measured data of the real TAS. The main focus of the parameter optimization was to determine the accuracy of the characteristic frequencies of the transducers which could be reached. The simulation model provides a powerful tool to analyze the 3D USCT TAS. Furthermore, it is now possible to design and optimize future transducers by including simulated results.

7968-24, Session 5

Comparison of simulated and measured nonlinear ultrasound fields

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In this paper results from an AS (angular spectrum) based on nonlinear simulation program are compared to water-tank measurements. A circular concave transducer with the diameter of 1 inch (25.4 mm) is used as the emission source. The measured pulses are firstly compared with the linear simulation of Field II, which will be used to generate the source for the AS simulation. The generated nonlinear field through propagation is measured by a hydrophone in the focal plane. The second harmonic component from the measurement is compared with the AS simulation, which is used to calculate both fundamental and second harmonic fields. The focused piston transducer with a center frequency of 5 MHz is excited by the waveform generator with a 6-cycle sine wave. The hydrophone is mounted in the focal plane 118 mm from the transducer. The point spread functions of both Field II and measurements are illustrated. The FWHM (full width at half maximum) values are 1.96 mm for measurements and 1.84 mm for the Field II simulation. The fundamental and second harmonic components of the experimental results are plotted compared with the AS simulations. The RMS (root mean square) errors of the AS simulations are 7.19% and 10.32% compared to the fundamental and second harmonic components of the measurements.

7968-25, Session 5

Fast k-space based evaluation of imaging properties of ultrasound apertures

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At the Institute for Data Processing and Electronics a three-dimensional ultrasound computer tomography (3D USCT) system for early breast cancer diagnosis is being developed. This method promises reproducible volume images of the female breast in 3D. Initial measurements and a simulation, which took several physical properties into account, led to a new aperture setup. But this simulation is to computational demanding to be used to evaluate different ‘virtual’ apertures which can be achieved by rotation and lifting of the system. In the optic theories a Fourier based approach was proposed to simulate imaging systems as linear systems. For the two apertures used in our project and one hypothetical linear array aperture this concept was evaluated compared to a reference simulation. An acceptable conformity between the new approach and the reference simulation exist. With this approach fast evaluation of optimal ‘virtual’ apertures for specific measurement objects and imaging constraints can be carried out within an acceptable time constraint.

7968-26, Session 5

Transmit beamforming techniques for suppressing grating lobes in large pitch ultrasonic phased arrays

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Clinical implementation of high-frequency ultrasound has conventionally been limited due to the difficulties in fabricating sufficiently small micro-array transducers. Specifically, if an array is desired with the ability to beam-steer to large angles, an inter-element pitch of approximately .5 is required to avoid grating lobe artifacts. At high-frequencies (30-60MHz), this introduces major fabrication challenges since the required element pitch is approximately 20 microns. A technique called Phase Coherence Imaging has been introduced for suppressing grating lobes in large-pitch arrays by calculating a weighting factor proportional to the instantaneous phase coherence of the element echoes. If the reflected echoes in the grating lobe region are relatively broadband, only some of the echoes will overlap and the resulting weighting factor will be less. Unfortunately, most beamforming techniques result in relatively narrowband echoes in the grating lobe region, making this technique less effective. We have developed a technique that splits the N-element transmit aperture into N/K transmit elements and N receive elements in order to better suppress grating lobes by increasing the bandwidth of the grating lobe echoes. We have also developed a technique that uses a probing pulse from a virtual point source behind the array in order to pre-calculate weighting factors from broadband echoes before conventional transmit beamforming is used. Radiation patterns have been simulated and the amount of grating lobe suppression has been quantified using the proposed techniques. It has been shown that these techniques are extremely effective in suppressing grating lobes in large-pitch phased-arrays, greatly simplifying high-frequency array fabrication.

7968-27, Session 5

A practical, robust approach to high resolution ultrasonic breast tomography

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Breast ultrasound tomography is considered a potentially safer, more reliable and more sensitive alternative to the widely used mammography for breast cancer diagnosis and screening. Vital to achieving this

potential is the development of imaging algorithms to unravel the very complex anatomy of the breast and its mechanical properties. Time-of-Flight Tomography (TFT) is the most prominent algorithm, producing sound-speed maps, but the underlying approximation of ray theory means that the algorithm is unsuitable for imaging structures where significant diffraction is present. Accordingly, the maximum resolution of the TFT algorithm is not sufficient to image the fine details of the breast on the scale of a few millimetres. Therefore, iterative full-wave inversion techniques are often subsequently applied to improve the resolution of the TFT image, but they are typically impractically slow or fail because of the uncertainties in the measurements such as 3D effects, noise or transducer characteristics. Presented here is a solution where the TFT algorithm is combined with the Diffraction Tomography (DT) method, avoiding iterations yet producing a high resolution sound-speed image. It is demonstrated via numerical simulations how it can successfully - and robustly - deal with a range of phenomena present in breast ultrasound experiments such as attenuation, density, 3D effects and transducer directivity while maintaining a high resolution. Being a direct method it is also fast; it is estimated the DT stage (when optimised) would only add around 20-30 seconds to the time of the TFT algorithm.

7964-26, Session 6

Section-thickness profiling for brachytherapy ultrasound guidance

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Purpose: Ultrasound (US) section-thickness (the elevation beamwidth) is a significant source of localization error in tracked US navigation. It is generally assumed that the US image is of zero thickness, which contradicts the fact that the acoustic beam can only be mechanically focused at a depth corresponding to its natural frequency resulting in a finite, non-uniformed elevation beamwidth. We examine the effects of this error on transrectal ultrasound navigation used in prostate brachytherapy. Method: In this work, we have engineered a beam-profiling device (a TRUS-bridge phantom) specifically tailored for standard brachytherapy systems to generate a complete section-thickness profile of a given TRUS transducer. The device was designed in CAD software and prototyped by a 3D printer. Result: The system has been tested on an AMS Brachytherapy Stepper (Acoustic MedSystems Inc., IL, USA) but is sufficiently general to be ported to other industry-standard brachytherapy systems in the market. Possessing the knowledge of section-thickness would provide the brachytherapy applications the ability to differentiate TRUS data by their likelihood of position errors (which are otherwise treated uniformly in the current practice). Conclusion: Initial results hypothesize that beam profiling increases the accuracy of feature detections and measurements in TRUS images, thereby improving the accuracy of planning and delivery of brachytherapy.

7968-28, Session 6

Ultrasound guidance of cardiac interventions

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Surgical procedures often have the unfortunate side-effect of causing the patient significant trauma while accessing the target site. Indeed, in some cases the trauma inflicted on the patient during access to the target greatly exceeds that caused by performing the therapy. Heart disease has traditionally been treated surgically using open chest techniques with the patient being placed "on pump" - i.e. their circulation being maintained by a cardio-pulmonary bypass or "heart-lung" machine.

Recently, techniques have been developed for performing minimally-invasive interventions on the heart, obviating the formerly invasive procedures that rely on pre-operative mages, combined with real-time images acquired during the procedure. Our approach is to register intra-operative images to the patient, and use a navigation system that combines intra-operative ultrasound with virtual models of instrumentation that has been introduced into the chamber through the heart wall. This presentation will illustrate the problems associated with traditional ultrasound guidance, and review the state of the art in real-time 3D cardiac ultrasound technology. In addition, it will discuss the implementation of an image-guided intervention platform that integrates real-time ultrasound with a virtual reality environment, bringing together the pre-operative anatomy derived from MRI or CT, representations of tracked instrumentation inside the heart chamber, and the intra-operatively acquired ultrasound images.

7968-29, Session 6

Quantification of prostate deformation due to needle insertion during TRUS-guided biopsy: comparison of hand-held and mechanically stabilized systems

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Prostate biopsy is the clinical standard for the definitive diagnosis of prostate cancer. To overcome the limitations of 2D TRUS-guided biopsy systems when targeting pre-planned locations, systems have been developed with 3D guidance to improve the accuracy of cancer detection. Prostate deformation due to needle insertion and biopsy gun firing is a potential source of error that can cause target misalignments during biopsies. We use non-rigid registration of 2D TRUS images to quantify the deformation during the needle insertion and the biopsy gun firing procedure, and compare this effect in biopsies performed using a handheld TRUS probe with those performed using a mechanically assisted 3D TRUS guided biopsy system. Along the needle axis, the mean difference in deformations from the handheld and mechanically assisted biopsy systems was 0.06 mm, and the mechanical system yielded greater deformational stability of the prostate during biopsy gun firing. We also analyzed the anisotropy of the tissue motion. Our results indicated that using the mechanical biopsy system, the motion is weakly anisotropic in the direction parallel to the needle, which is preferable from a targeting standpoint given the long, narrow cylindrical shape of the biopsy core.

7968-30, Session 6

A hybrid surface/image based approach to facilitate ultrasound/CT registration

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Purpose: Registration of intra-operative ultrasound with preoperative CT is highly desirable as a navigational aid for surgeons and interventional radiologists. Image-based solutions generally achieve poor results due to substantially different image appearance of ultrasound and CT. A method is presented that uses surface information and tracked ultrasound to improve registration results.

Methods: Tracked ultrasound is combined with surface and image-based registration techniques to register ultrasound to CT. Surface data is acquired using an optically tracked range sensor, for example time-of-flight camera. Range data is registered to CT using robust point-set registration; this registration provides an approximate transformation from tracker to CT coordinates. The ultrasound probe is also optically tracked. The probe position and surface-based registration provide a first estimate

for the position of the ultrasound image in CT coordinates. This estimate is subsequently refined by a final image-based registration stage.

Results: Initial tests using Coherent Point Drift algorithm for registering surface data to CT show favorable results. Tests using both simulated and real time-of-flight range data have good convergence over a wide initial translation and rotation misalignment domain.

Conclusion: Preliminary testing using time-of-flight surface data suggests that surface to CT registration may be useful as an initial guess enabling later more precise (but less robust) image based methods for registering ultrasound images to CT. We believe this method will enable image-based algorithms to robustly converge to an optimal registration solution.

A novel approach is presented addressing the problem of registering ultrasound and CT images to enable ultrasound image fusion for CT planned interventions.

Tracked ultrasound is combined with surface-based registration to provide an initial guess that enables a subsequent image-based registration step.

Initial tests using CPD algorithm with simulated and real time-of-flight range data for surface registration to CT provide favorable results.

We believe this method will enable image-based algorithms to converge to an optimal registration solution in a robust manner.

7968-31, Session 6

Calibration of a 3D ultrasound system to an electromagnetic tracking system

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The use of electromagnetic (EM) tracking is an important guidance tool that can be used to aid procedures requiring accurate localization such as needle injections or catheter guidance. Using EM tracking, the information from different modalities can be easily combined using pre-procedural calibration information. These calibrations are performed individually, per modality, allowing different imaging systems to be mixed and matched according to the procedure at hand. In this work, a framework for the calibration of a 3D transesophageal echocardiography probe to EM tracking is developed. The complete calibration framework includes three required steps: data acquisition, needle segmentation, and calibration. Ultrasound (US) images of an EM tracked needle must be acquired with the position of the needles in each volume subsequently extracted by segmentation. The calibration transformation is determined through a registration between the segmented points and the recorded EM needle positions. Additionally, the speed of sound is compensated for since calibration is performed in water that has a different speed then is assumed by the US machine. A statistical validation framework has also been developed to provide further information related to the accuracy and consistency of the calibration. Further validation of the calibration showed an accuracy of 1.39 mm.

7968-34, Session 7

Experimental observation of super-resolution imaging in highly attenuative materials

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The resolution of conventional beamforming techniques is dictated by the Rayleigh criterion that excludes the possibility of detecting details of an object that are spaced less than a wavelength apart. Therefore in attenuative media, there exists a fundamental trade-off between resolution and imaging depth because the short wavelengths required to achieve high resolution are rapidly attenuated with propagation distance due to energy dissipation and scattering. The possibility of obtaining resolution beyond the Rayleigh criterion i.e. super resolution, has been studied by several authors. These studies have shown that imaging formation techniques based on inverse scattering rather than standard beamforming can lead to super resolution. Importantly, all the experimental demonstrations of super resolution imaging have been carried out in media where attenuation effects can be neglected. In this paper we present the first experimental demonstration of subwavelength resolution in glycerol whose ultrasonic attenuation is in the order of 1dB/cm/MHz which is close to the attenuation observed in human tissue. Using a commercial clinical scanner and strands of human hairs we show that the inverse scattering approach outperforms current sonography revealing features that are undetected by sonography.

7968-35, Session 7

An object-oriented multi-threaded software beam formation toolbox

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Focusing and apodization are an essential part of signal processing n ultrasound imaging. Although the fundamental principles are simple, the dramatic increase in computational power of CPUs, GPUs, and FPGAs motivates the development of software based beamformers, which further improves image quality (and the accuracy of velocity estimation). For developing new imaging methods, it is important to establish proof-of-concept before using resources on real-time implementations. With this in mind, an effective and versatile Matlab toolbox written in C++ has been developed to assist the development of new beam formation strategies. It is a general 3D implementation capable of handling a multitude of focusing methods, interpolation schemes and parametric and dynamic apodization. Despite being flexible, it is capable of exploiting parallelization on a single computer, or on a cluster, or both. On a single computer, it mimics the parallization in a scanner containing multiple beam formers. The focusing is determined using the positions of the transducer elements, presence of virtual sources, and the focus points. For interpolation, a number of interpolation schemes can be chosen, e.g. linear, polynomial or cubic splines. Apodization can be specified by a number of window function of fixed size applied on the individual elements as a function of distance to a reference point, or it can be dynamic with an expanding or contracting aperture to obtain a constant F-number, or both. On a standard PC with a Quad-Core Xeon processor running at 2.2 GHz, the toolbox can beamform 300.000 points using 700.000 data samples in less than 4 seconds using a transducer with 192 elements, dynamic apodization in transmit and receive, and cubic splines for interpolation. This is 19 times faster than our previous toolbox.

7968-36, Session 7

Feasibility of a combined B-mode (ARFI) colorflow Doppler system for real-time, volumetric scanning

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Acoustic radiation force impulse (ARFI) imaging has been previously described for the visualization of the cardiovascular system, particularly for the imaging of cerebral and lower-limb vascular disease. It is known that plaque imposes a 3-dimensional burden, and that multiple scans are often required from multiple angles to fully characterize plaque. It would be convenient if an entire plaque volume could be acquired, either using a 3D system or 2D freehand scanning. Currently, ARFI vascular imaging uses single-frame acquisition, with acquisition times ranging from 100-200ms. Such a system would be cumbersome for real-time, freehand scanning.

In this work, we evaluate the feasibility of using ARFI for freehand, real-time scanning of the cardiovascular system. New techniques are presented which acquire B-mode / ARFI/ and Colorflow Doppler (BACD) information in 50ms. The temporal and spatial stability of the system is analyzed in vivo at frame-rates from 10Hz -20Hz in the carotid artery of

a canine model. Finally, 3D imaging feasibility is evaluated on custom, soft-plaque phantoms mounted in a flow-rig. Phantoms are scanned by translating the aperture in the elevational dimensional at different rates. Doppler and ARFI volumetric data is then volume-rendered for display.

For most frames, in vivo proximal and distal arterial walls were well resolved, with an average displacement of 1.1µm.Lateral and temporal standard deviations were 0.3 µm and 0.1 µm, suggesting that ARFI displacement frames are relatively stable throughout the cardiac cycle. 3D ARFI and flow volumes were well-visualized from the phantom data.

7968-37, Session 7

Turbulence intensity in a region of interest 2cm distal to the carotid bifurcation in a family of seven anthropomorphic flow phantoms

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An in vitro flow system has been used to assess the flow disturbances downstream of the stenosis in a family of seven carotid bifurcation phantoms modelling varying plaque build-up both axially symmetrically (concentrically) and asymmetrically (eccentrically). Radio frequency data were collected for 10 s at each of over 1000 sites within each model, and a sliding 1024-point FFT is applied to the data to extract the Doppler spectrum every 12 ms. From this, the ensemble average over 10 cardiac cycles of the spectral mean velocity, and the root mean square over these same 10 cardiac cycles - the turbulence intensity (TI), can be obtained as a function of an ensemble averaged cardiac cycle at each spatial point in all phantoms. TI was investigated by looking at the average over a 25 mm2 square region of interest in the ICA centered 2 cm distal to the apex of the bifurcation.

TI in the region of interest increased with stenosis severity; at 23ms following peak systole, the time point when TI was maximal for the majority of models, this ranged from 2.4±0.1 cm/s in the non-diseased model to 6.6±0.3, 16.0±1.4 and 26.1±1.3 cm/s in the 30, 50 and 70% concentrically stenosed (by NASCET criteria) models, respectively. Similarly, TI was 8.3±0.7, 19.9±1.1, and 26.2±1.2 cm/s in the 30, 50 and 70% eccentrically stenosed models, respectively. Differences in TI between models, both in increasing stenosis severity and between eccentricities, were statistically different except between the 70% concentric and eccentric models.

7968-38, Session 7

Left ventricular 2D flow pattern estimation by combining speckle tracking with Navier-Stokes based regularization in an iterative way

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Ultrasound imaging with low dose contrast injection would be of interest to better characterize the cardiac flow dynamics inside the left ventricle (LV). We previously proposed a new estimation method by regularizing each initial motion estimate obtained through speckle tracking with the modified Navier-Stokes equations. However, fast motion of the blood and out-of-plane flow make the tracking too noisy to benefit from the regularization when the inflow velocities are high. The aim of this study was therefore to add the Navier-Stokes based regularization in an iterative manner in order to improve the initial speckle tracking results. The method was tested in a Computational Fluid Dynamics (CFD) based simulation environment previously introduced by our lab.

A dynamic 3D anatomical model of the LV was combined with a realistic inflow velocity profile to build a CFD flow vector field (Fluent 12.1, ANSYS). The motion of injected bubbles (density=500/ml) was simulated and used as input to an ultrasound simulator (COLE) to obtain a 2D B-mode image sequence. On two subsequent images in diastasis, block-matching was applied using normalized cross-correlation as a similarity measure and spline-interpolation for subsample motion estimation. To regularize the velocity estimates, the difference between the measured and the regularized velocity field was added as an external force to a finite difference implementation of the Navier-Stokes equations. This regularized velocity field was used as prior to the speckle tracking procedure between the following pair of images by guiding and reshaping the search region appropriately. This iterative approach of matching and regularization was performed in the forward and the backward temporal direction to obtain the flow fields of the whole filling phase. The Root-Mean-Square-Error (RMSE) of all velocity estimates (amplitude & angle) within each frame was calculated using the CFD velocity vector field as the ground truth and these findings were contrasted to pure speckle tracking.

The analysis showed that iterative regularization improved the velocity estimates significantly both in amplitude and in angle for inflow velocities above 0.25 m/s. In this study, we could thus show that LV flow tracking by combining speckle tracking with Navier-Stokes based regularization in an iterative manner improves the accuracy of the speckle tracking results even at high inflow velocity.

7968-54, Session 7

In-vivo breast imaging with ultrasound tomography: results at the Karmanos Cancer Institute

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Our laboratory has focused on the development of UST for breast imaging. To that end we have been developing and testing a clinical prototype in the Karmanos Cancer Institute's (KCI) breast center. The development of our prototype has been guided by clinical feedback from data accumulated over the last 5 years. Our techniques generate whole breast reflection images as well as images of the acoustic parameters of sound speed and attenuation. The combination of these parameters along with qualitative reflection parameters reveals the potential to characterize masses. Fusion imaging, utilizing thresholding, is shown to visualize mass characterization and facilitates separation of cancer from benign masses. These results indicate that operator-independent whole-breast imaging and the detection and characterization of cancerous breast masses are feasible using acoustic tomography techniques.

Analyses of the prototype images suggests that we can detect the variety of mass attributes noted by current ultrasound-BIRADS criteria, such as mass shape, acoustic mass properties and architecture of the tumor environment. These attributes help quantify current BIRADS criteria (e.g. "shadowing" or high attenuation) and provide greater possibilities for defining a unique signature of cancer. The potential for UST to detect and characterize breast masses was quantified using an ROC analysis of UST measurements from the most recent cohort of patients imaged with the latest version of our prototype.

7968-14, Poster Session

Skeletonization approach for characterization of benign vs. malignant single thyroid nodules using 3-D contrast enhanced ultrasound

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High-resolution ultrasonography (HRUS) is the most frequently used tool for identification, assessment and follow up of thyroid lesions. Even though it has been demonstrated that malignancy is related to common

features in HRUS B-Mode images (i.e., microcalcifications, marked hypoechogenicity, irregular margins, and the absence of a hypoechoic halo around the nodule), interpretative pitfalls remains.

We developed and tested a system (ThyScreenCEUS) for the characterization of the intranodular vascularization of single thyroid nodules in 3-D CEUS images. The 3-D volumes were preprocessed and skeletonized. Seven vascular parameters were computed on the skeletons: number of vascular trees; vascular density; number of branching nodes; mean vessel radius; 2-D and 3-D tortuosity; and inflection count metric. We applied our procedure on the 3-D volumes we acquired on 20 thyroid lesions (10 malignant). Malignancy was assessed by fine needle biopsy and histological report.

We found that malignant lesions are highly perfused by a dense vascular bed. Such vessels also originate several branches, thus increasing the overall density of the vasculature in the lesion. The tortuosity of the malignant vascularization was found clearly higher than that of benign nodules.

From a clinical point of view, this study could help fostering the use of CEUS in the differential diagnosis of thyroid nodules.

7968-32, Poster Session

A compounded direct pixel beamforming method for medical ultrasound imaging

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In medical ultrasound imaging, scan conversion is used to geometrically transform polar coordinate ultrasound data into Cartesian raster data for display. In scan conversion, to avoid Moire undersampling artifacts, various interpolation techniques, such as nearest neighbor and bilinear, are applied. However, this interpolation-based scan conversion introduces blurring of fine details in ultrasound images. In this paper, a new beamforming technique, called as compounded direct pixel beamforming (CDPB), is proposed to remove blurring artifacts from scan conversion. In CDPB, receive focusing is performed directly on each display pixel in Cartesian coordinates with raw radio-frequency (RF) data from two adjacent transmit firings so that artifacts from scan conversion can be completely removed. To evaluate the proposed CDPB method, 64-channel pre-beamformed RF data were captured by a commercial ultrasound machine (SA-9900, Medison Corp., Seoul, Korea) with a tissue mimicking phantom (ATS Laboratories, Bridgeport, CT, USA). To quantify the performance of the proposed method, the information entropy contrast (IEC) value was measured. From the experiments, the proposed method provides 2.8 improvements in the IEC over the conventional scan conversion method. These results indicate that the proposed new beamforming method could be used for enhancing the image quality in medical ultrasound imaging.

7968-33, Poster Session

The new efficient multi-beamforming method base on multiple-access register block on a post-fractional filtering architecture

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In medical ultrasound imaging, a multi-beamforming (MBF) technique has been widely used in various applications where fast data acquisition is essential, e.g., heart. To reduce the hardware complexity associated with the use of MBF, the time-sharing method (i.e., MBF-TS) was previously proposed. In MBF-TS, instead of using multiple dynamic receive beamformers (MBF-CON), the beamforming frequency is lowered. While the MBF-TS can significantly decrease the hardware complexity, it suffers from the degradation in image quality. In this paper, the new multi-beamforming method based on multiple access register (MBF-MAR) on a post-fractional filtering architecture is proposed. To evaluate the performance of the proposed MBF-MAR method, the in vitro experiments were conducted with a tissue mimicking phantom where 64-channel pre-beamformed radio-frequency (RF) data were captured with a commercial ultrasound system (SONOLINE G40, Siemens, Inc., USA) using a 3-MHz phased array probe. The proposed MBF-MAR method shows 4.7 dB and 0.6 improvements in signal-to-noise ratio and contrast-to-noise ratio, respectively, compared to the MBF-TS method. In addition, the MBF-MAR showed the similar results with the in vivo thyroid experiments. These results indicate the proposed MBF-MAR can provide improved image quality over the conventional MBF-TS method while substantially reducing the hardware complexity compared to the MBF-CON method.

7968-39, Poster Session

Impedance-controlled ultrasound probe

M. W. Gilbertson, B. W. Anthony, Massachusetts Institute of Technology (United States)

An actuated hand-held impedance controlled ultrasound probe has been developed. The controller maintains a prescribed contact state (force and velocity) between the probe and a patient's body. The device will enhance the diagnostic capability of free-hand elastography and swept-force compound imaging, and also make it easier for a technician to acquire repeatable (i.e. directly comparable) images over time. The mechanical system consists of an ultrasound probe, ballscrew-driven linear actuator, and a force/torque sensor. The feedback controller commands the motor to rotate the ballscrew to translate the ultrasound probe in order to maintain a desired contact force. It was found that ultrasound technicians, with the control system engaged, maintain a constant contact force with 20 times less variation than without the controller engaged. The system was used to determine the elastic properties of soft tissue.

7968-40, Poster Session

Fast algorithm for respiratory motion correction in free-breathing contrast-enhanced ultrasound imaging

Z. Ji, M. Ding, F. Meng, Y. Ming, Huazhong Univ. of Science and Technology (China)

Respiratory motion affects the accurate quantification of the hepatic fusion, which does not be benefit the early detection and treatment of hepatic cancers. A new strategy based on template matching is proposed to correct respiratory motion in the free-breathing time-series contrast-enhanced ultrasound (CEUS) images. Ultrasound machines generally have a dual-display feature of contrast and tissue windows under contrast-enhanced mode. The tissue window is used to track the targeted tumor in the contrast window. Therefore, the registration of contrast images is first achieved by the registration of the corresponding tissue images due to the low variation of grey level in the tissue image. Then, a simple double-selection method is proposed to select the similar images from a large number of successive matched images via the global and local threshold setting. Finally, the motion-corrected contrast images can be acquired by using the position mapping. This strategy was tested on 4 free-breathing CEUS image sequences using the sum of absolute differences metric. Results showed that the time-intensity curves could be extracted more accurately with this strategy. Moreover, the quality of curve fitting and the corresponding parametric imaging computed on the motion-corrected sequences was improved significantly. In conclusion, the image-based strategy can quickly correct the respiratory motion in CEUS image sequences, which is potentially suitable for the local quantification of hepatic perfusion studies.

7968-41, Poster Session

Xampling in ultrasound imaging

G. Danin, A. Feuer, N. Wagner, Technion-Israel Institute of Technology (Israel); Z. Fridman, GE Healthcare (Israel)

Recent developments of new medical treatment techniques put challenging demands on ultrasound imaging systems in terms of both image quality and raw data size. Traditional sampling methods result in very large amounts of data, thus, increasing demands on processing hardware and limiting the flexibility in the post-processing stages.

The application of Compressed Sensing (CS) ideas to analog signals was introduced by one of the authors previously and the term Xampling coined. Our paper presents a novel attempt of applying these ideas to ultrasound imaging. The result is a system with significantly reduced sampling rates which, in turn, means significantly reduced data size while maintaining the quality of the resulting images. Three fundamental properties of the measured ultrasound signals are used:

1. Ultrasound signals consist of a stream of delayed and weighted versions of a known pulse shape.

2. The temporal search area for these pulses, related to the scanning depth, is pre-determined.

3. The number of pulses (or at least the upper bound of it), representing the number of alternating tissues within the scanned area, is also known.

By integrating our unique sampling scheme and beam forming sequence we achieve the desired target of significantly reducing the processed data size, while preserving the quality of the extracted image. We describe the process we test and present some preliminary results using both simulated and real data, illustrating the potential of our approach.

7968-42, Poster Session

The causal lossy impulse response of a circular piston evaluated in the time and frequency domains for power law media

C. T. Johnson, R. J. McGough, Michigan State Univ. (United States)

We have recently derived analytical expressions for the time domain Green's function that exactly solve the wave equation for power law media with an attenuation term that is proportional to frequency to the 'y' power. These analytical expressions are causal for power law exponents 'y' less than one and noncausal for power law exponents 'y' greater than or equal to one. Causal expressions for the lossy impulse response of a circular piston are obtained for power law exponents less than one when the impulse response of the time-domain Rayleigh-Sommerfeld integral is evaluated by superposing the causal Green's function in space and in time. The lossy impulse response is also computed in the frequency domain for the same piston. The exact arrival time and the approximate departure time for the impulse response are directly obtained from the time domain expression, whereas extracting this information from the frequency domain expression is much more difficult. Numerical results are computed in the time and frequency domains for a circular piston with a four wavelength radius. The velocity potential is also computed for a 50% bandwidth pulse with a center frequency of 2MHz using frequency domain and time domain methods, and the advantages and disadvantages of calculating the response in each domain are described. Future plans to extend these results to the fast nearfield method and the FOCUS software package for rapid nearfield pressure calculations will also be discussed.

7968-43, Poster Session

Tissue classification using depth-dependent ultrasound time series analysis: In vitro animal study

F. Imani, Queen's Univ. (Canada); M. I. Daoud, M. Moradi, P. Abolmaesumi, The Univ. of British Columbia (Canada); P. Mousavi, Queen's Univ. (Canada)

Time series analysis of ultrasound radio-frequency (RF) signals has been shown to be an effective tissue classification method. Previous studies of this method for tissue differentiation at high and clinical-frequencies have been reported. In this paper, analysis of RF time series is extended to improve tissue classification at the clinical frequencies by including novel features extracted from the time series spectrum. The primary feature examined is the Mean Central Frequency (MCF) computed for regions of interest (ROIs) in the tissue extending along the axial axis of the transducer. In addition, the intercept and slope of a line fitted to the MCF-values of the RF time series as a function of depth have been included. To evaluate the accuracy of the new features, an in vitro animal study is performed using three tissue types: bovine muscle, bovine liver, and chicken breast, where perfect two-way classification is achieved. The results show statistically significant improvements over the classification accuracies with previously reported features.

7968-44, Poster Session

Bedside assistance in freehand ultrasonic diagnosis by real-time visual feedback of 3D scatter diagram of pulsatile tissue-motion

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By real-time visual feedback of 3D scatter diagram of pulsatile tissue-motion, freehand ultrasonic diagnosis of neonatal ischemic diseases has been assisted at the bedside. The 2D ultrasonic movie was taken with a conventional ultrasonic apparatus (ATL HDI5000) and ultrasonic probes of 5-7 MHz with the compact tilt-sensor to measure the probe orientation. The real-time 3D visualization was realized by developing an extended version of the PC-based 2D visualization system. The software was originally developed on the DirectX platform and optimized with the streaming SIMD extensions. The 3D scatter diagram of the latest pulsatile tissues has been continuously generated and visualized as projection image with the ultrasonic movie in the current section at about 15 fps. It revealed the 3D structure of pulsatile tissues such as middle and posterior cerebral arteries, Willis ring and cerebellar arteries, in which pediatricians have great interests in the blood flow because asphyxiated and/or low-birth-weight neonates have a high risk of ischemic diseases such as hypoxic-ischemic encephalopathy and periventricular leukomalacia. Since the pulsatile tissue-motion is due to local blood flow, it can be concluded that the system developed in this work is very useful to assist freehand ultrasonic diagnosis of ischemic diseases in the neonatal cranium. Further study on assisting performance of the developed system is now still in progress.

7968-45, Poster Session

Interference based speckle filter

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Speckle noise is a random granular texture produced by mutual interference of a set of scattered wavefronts, so it is inherent to ultrasonic

imaging. Depending on the phase of the wavefronts the interference may be constructive or destructive. In this work, we developed an interference based speckle filter (ISF), whose first step is to attenuate the destructive interference, because it carries little information about the imaged structures. In order to do that, we considered, for each pixel, the maximum between the median and the original value. To eliminate the remaining bright speckles, we applied a median filter. The resulting image had minimized speckle effects.

We have created two basic numeric phantoms, a linear array ultrasound and an intravascular ultrasound phantoms, and we have simulated 20 random initializations of speckle noise for each phantom. Then, we filtered the noisy images using several filters: ISF, median, Wiener, anisotropic diffusion and speckle reducing anisotropic diffusion (SRAD). To evaluate and compare their performances, we have calculated mean and standard deviation of a homogeneous region, square root mean error and structural similarity (SSIM) for each one. ISF presented an overall 0.91 rate for SSIM, while SRAD and Wiener filter performed SSIM 0.87 and 0.85 rates, respectively.

This filter is easy to implement, because it requires only a sequence of three basic operations (Median, MaxValue and Median) and it is also easy to set the input parameters (the two radii of the median filters). Mostly important, it is able to smooth speckle effects without blurring edges.

7968-46, Poster Session

Pad-printed thick-film transducers for high-frequency and high-power applications

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High-frequency-ultrasound transducers are widely used but are typically based either on planar piezoceramic sections that are lapped down to smaller thicknesses or on piezopolymers that may be deformed into more complex geometries. Piezoceramics then require dicing to obtain arrays or can be fractured into spherical geometries to achieve focusing. Piezopolymers are not as efficient for very small element sizes and are normally available only in discrete thicknesses. Thick-film transducers provide a means of overcoming these limits because the piezoelectric film is deposited with the required thickness, size and geometry, thus avoiding any subsequent machining. Thick-film transducers offer the potential of a wide range of geometries such as single-elements and annular or linear arrays. Here, a single-element focused transducer is developed using a piezoceramic composition adapted to high-power operation which is commonly used at standard MHz frequencies. After fabrication, the transducer is characterized through complex electrical impedance measurements. Using specific transmit-receive electronics and a water tank adapted to high-frequency devices, the transducer is then excited using a short pulse to evaluate its bandwidth and imaging capabilities. Finally, it is excited in burst mode using several power levels to evaluate its capacity to produce high-intensity focused ultrasound at frequencies over 20 MHz.

7968-47, Poster Session

Ultrasound elastography using regularized phase-zero cost function initialized with dynamic programming

S. Sefati, H. Rivaz, E. Boctor, G. D. Hager, The Johns Hopkins Univ. (United States)

Elastography, computation of elasticity modulus of tissue is one of medical imaging methods with applications such as tumor detection and ablation therapy. Phase-based time delay estimation methods exploit the frequency information of the RF data to obtain strain estimates [1]. Although iterative Phase zero estimation is more computationally efficient in comparison to methods that seek for the absolute maximum cross-correlation between precompression and postcompression echo signals, it is quite sensitive to noise. The reason for this sensitivity is that for this iterative method an initial guess for the time shift is needed for each pixel. To estimate time shifts for the sample k, the time shift resulted from iterative phase zero method applied on sample k–1 is used as an initial value. This makes the method sensitive to noise because the error is propagating sample by sample and if the method gets unstable for any pixel, it will give unstable result for the following pixels in image line. Proposed strategy in this work to overcome this problem is to first estimate the strain using Dynamic Programming [2] and use the results from DP as an initial guess of displacement for each pixel in iterative Phase zero method. Recently, regularized methods that incorporate the prior of tissue continuity in time delay estimation have been shown to produce low-noise and high contrast strain images [3]. In this work, we also incorporate the prior of tissue motion continuity in the phase zero method to make the zero-phase method more robust to signal decorrelation.

7968-48, Poster Session

Improved detectability of hypoechoic regions with short-lag spatial coherence imaging: experimental validation

M. Jakovljevic, J. J. Dahl, G. E. Trahey, Duke Univ. (United States)

The ability of an ultrasound system to differentiate signals in the presence of phase aberration and clutter is of key clinical importance. Phase aberration and clutter cause incoherent interference of the transmit and/or receive pressure fields and have been identified as major sources of image degradation in obese patients. Therefore, suppressing their negative effects would significantly improve diagnostic value of ultrasound.

We have recently developed a novel method called short-lag-spatial-coherence (SLSC) imaging that allows formation of high quality ultrasound images in the presence of clutter. The method is based on the van-Cittert-Zernike theorem. Specifically, the metric used to reconstruct the images is determined by the spatial coherence of the pressure field at the surface of the transducer.

We compare SLSC and conventional delay-and-sum beamforming techniques using data acquired on human liver in vivo. We acquired single-channel RF data to form matched SCLC lines and A-lines of the liver vasculature and gall-bladder. We show that SLSC method results in higher SNR and CNR while keeping contrast and resolution comparable to that of conventional B-mode. SLSC lines were measured to have SNR of 6.03±0.6, CNR of 3.06±1.35, and contrast of 0.45±0.14. A-lines had SNR of 1.99±0.03 , CNR of 0.83±0.23, and contrast of 0.51±0.1.

7968-49, Poster Session

Needle detection in 3D ultrasound

G. Houël, C. Wachinger, N. Navab, Technische Univ. München (Germany)

Ultrasound-guided percutaneous needle insertions are widely used techniques in current clinical practice. Some of these procedures remain quite difficult because of poor observability of the needle in the ultrasound image. There have been recent efforts to improve needle detection in 2D images, but the acquisition itself requires both experience and concentration in order to keep the needle in the observation plane. Indeed, in 2D images, the observation zone is limited to a plane, where a crossing needle only appears as a point. The next step coming along with the development of 3D ultrasound acquisition is the image-based detection of needle in a volume.

In this paper, we present a new method to detect the needle in 3D ultrasound. It involves two integrations and uses a 2D Hough-based detection approach. Different techniques using derivation or matrix

decomposition have been tested and compared to reduce the influence of speckle noise and low contrasts in ultrasonographic volumes, and improve the overall detection performance. Experimental results, on multiple ultrasound data sets, show the good performances of the proposed strategies.

7968-50, Poster Session

A user-friendly system for ultrasound carotid intima-media thickness image interpretation

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Ultrasound Carotid Intima-Media Thickness (CIMT) screening is a technically mature and accurate technology [1, 2]. Given the high morbidity, mortality and the large societal burden associated with CV diseases, as a safe yet inexpensive tool, CMIT attracts increasing attentions for cardiovascular (CV) risk stratification [1]. However, CIMT requires a precise measure of the thickness of the intima and media layers of the carotid artery. Not only is it tedious and time consuming, but also demands specialized expertise and experience. To this end, we have developed a highly user-friendly system for semiautomatic CIMT image interpretation. Our contribution is the application of active contour models (snake models) with hard constraints, leading to an accurate, adaptive and user-friendly border detection algorithm. A comparison study with the CIMT measurement software in Siemens Syngo® Arterial Health Package shows that our system gives a small bias in mean (0.049 ± 0.051mm) and maximum (0.010 ± 0.083 mm) CIMT measures and offers a higher reproducibility (average correlation coefficients were 0.948 and 0.844 in mean and maximum CIMT respectively ($P < 0.001$)). This superior performance is attributed to our novel interface design for hard constraints in the snake models.

7968-51, Poster Session

Some observations on the optimal design of breast ultrasound tomography systems

P. E. Huthwaite, F. Simonetti, Imperial College London (United Kingdom)

Breast ultrasound tomography (BUST) is an important developing technology, with potential for improvements in safety, sensitivity and reliability over mammography. The challenge of recreating images of the breast anatomy and mechanical properties is exaggerated by the huge complexity of the structures within the breast that result in a range of complex scattering phenomena. The two considered to be most significant are investigated here: 3-D effects and the small scale - effectively random - variations in breast density and sound-speed. Importantly, these effects are not directly related to a state of disease and therefore can reduce the sensitivity of BUST when they become dominant. The relative weight of these ‘nuisance’ aspects of scattering is dependent on the characteristics of the detectors used to measure the scattered field. These include the relative distance between the detectors and the breast as well as their size. As an example, studies in geophysics have shown that as the scattered field emerging from an object travels away from the object it undergoes a healing process by means of which the wavefield loses its ‘memory’ of the object. The further the wavefield propagates from the object the more acute the healing effect is. The objective of this paper is to better understand these effects in the context of breast cancer detection and their implications on imaging performance to allow an optimal design of BUST technology.

7968-52, Poster Session

Multi-frequency super-resolution ultrasound imaging

L. Huang, Los Alamos National Lab. (United States); F. Simonetti, Imperial College London (United Kingdom)

Ultrasound could be an attractive alternative to breast microcalcifition detection, but it requires significant improvement in image quality and resolution of ultrasound imaging. Using a higher-frequency ultrasound could produce a higher-resolution image, but it also greatly decreases the imaging depth due to ultrasound attenuation. Recently, we have demonstrated that the super-resolution ultrasound imaging using single frequency data has the potential to detect breast microcalcifications. In this study, we explore the use of multi-frequency components of broadband ultrasound data for super-resolution ultrasound imaging to further improve image quality and resolution. Super-resolution imaging is based on singular value decomposition of synthetic aperture ultrasound data from a linear transducer array. The method makes use of the full waveform of ultrasound data and a factorization scheme for image reconstruction. Multi-frequency data help reduce image noise and improve image resolution of super-resolution ultrasound imaging. We use ultrasound data acquired by a synthetic aperture ultrasound scanner to demonstrate the image improvement of multi-frequency super-resolution ultrasound imaging.

7968-53, Poster Session

Navigation with local sensors in handheld 3D ultrasound: initial in-vivo experience

P. J. Stolka, E. Boctor, The Johns Hopkins Outpatient Ctr. (United States)

Handheld 2D ultrasound is useful for intra-operative imaging, but requires some reconstruction effort in order to create 3D-US volumes, unless one is using large and expensive 3D-US probes. Unlike common probe tracking approaches involving either global or local tracking (suffering from jitter and complexity or from drift), we propose to use a combination of very low-cost local sensors - optical mice and accelerometers - to reconstruct the probe trajectory with multiple degrees of freedom, but no global tracking overhead. Coupled with a dynamically expanding, pixel-nearest-neighbor 3D-US volume reconstruction, we report our experiences from a first series of in-vivo human volunteer experiments.

We replaced absolute tracking with a solution that is centered on using local sensors for generation of limited-DoF (relative, as opposed to absolute) localization data [5] [?]. This data from a set of several such sensors can then be combined to provide complete position information through iterative global trajectory reconstruction. This results in a very small footprint in computational complexity and additional hardware. Unlike previous approaches (e.g. using optical trackers and gyroscopes), our approach limits strong long-term orientational drift with a setup that is algorithmically, numerically, and physically simpler and does not suffer from these drawbacks.

In this work, we also report initial experiences from a first series of human volunteer experiments, concentrating on the usability of the approach with a first prototype.

7968-55, Poster Session

Is it possible to measure thermal expansion in real-time?

H. Rivaz, P. J. Stolka, E. Boctor, The Johns Hopkins Outpatient Ctr. (United States)

The clinical success of thermal ablation therapy can be greatly improved with an imaging system for monitoring temperature. Since temperature rise will increase the speed of sound in the tissue, and since an increase in the speed of sound cause the tissue to appear closer to the ultrasound probe, previous work focuses to estimate apparent motion of the tissue as a measure for temperature rise. However, increase of the speed of sound is not the only factor that contributes the image of the hot tissue to move closer towards the probe: thermal expansion will also cause the tissue to physically move. This makes temperature estimates biased and requires cumbersome calibration process to eliminate the bias.

In this paper, we present a novel idea that measures thermal expansion of the tissue as a result of temperature rise using 3D ultrasound. As a preliminary work that shows the possibility of such measurements and to enable the validation of our results, we simulate thermal expansion by applying external deformations to tissue mimicking phantom. The external deformation is applied by an accurate linear stage while the volumetric ultrasound images are acquired using a robot synchronized with the ultrasound acquisition system. We use regularize and real-time motion-tracking techniques previously developed in our team to track the expansion (i.e. motion) of the phantom. Our preliminary results show that motion tracking can be used to estimate tissue expansion.