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6233-01, Session 1

Analytical comparison of the matched filter and orthogonal subspace projection detectors in structured models for hyperspectral images

P. Bajorski, Rochester Institute of Technology

In this paper, we perform an analytical comparison of two well-known detectors-the matched filter detector (MFD) and the orthogonal subspace projection (OSP) detector for the subpixel target detection in hyperspectral images under the assumption of the structured model. The OSP detector (equivalent to the least squares estimator) is a popular detector utilizing background signature information. On the other hand, the MFD is intended for a model without background information, and it is often used for its simplicity. The OSP detector seems to be more reliable because it removes the interference of background signatures. However, it has been demonstrated in the literature that sometimes the MFD can be more powerful. In this paper, we show analytical results explaining the relationship between the two detectors beyond the anecdotal evidence from specific hyperspectral images or simulations. We also give some guidelines on when the MFD may be more beneficial than the OSP, and when the OSP is better because of being more robust against a wide range of conditions.

6233-02, Session 1

Adaptive smoothing for subpixel target detection in hyperspectral imaging

P. Bajorski, Rochester Institute of Technology; P. Hall, The Australian National Univ. (Australia)

In practical target detection, we often deal with situations where even a relatively small target is present in two or more adjacent pixels, due to its physical configuration with respect to the pixel grid. At the same time, a relatively large but narrow object (such as a wall or a narrow road) may be collectively present in many pixels but be only a small part of each single pixel. In such cases, critical information about the target is spread among many spectra and cannot be used efficiently by detectors that investigate each single pixel separately. We show that these difficulties can be overcome by using appropriate smoothing operators. We introduce a class of Locally Adaptive Smoothing detectors and evaluate them on three different images representing a broad range of blur that would interfere with the detection process in practical problems. The smoothing-based detectors prove to be very powerful in these cases, and they outperform the traditional detectors such as the constrained energy minimization (CEM) filter or the one-dimensional target-constrained interference-minimized filter (TCIMF).

6233-03, Session 1

Kernel canonical correlation analysis for hyperspectral anomaly detection

H. Kwon, N. M. Nasrabadi, Army Research Lab.

Canonical correlations measure the linear dependency between two sets of signal vectors obtained from two separate data sources. The linear dependency in canonical correlation analysis (CCA) is actually measured by the cosines of the principal angles between the linear subspaces spanned by the respective signal vectors. Therefore, if the two-channel signal vectors are linearly correlated a high level of correlations is obtained because the respective subspaces are very close together. CCA can be used as an effective tool for spectral anomaly detection for hyperspectral imagery where the two-channel signal vectors are the local spectral vectors and their neighboring background vectors obtained from a local dual rectangular window. The dual rectangular window separates a local area into two regions, the inner window region (IWR) and the outer window region (OWR). The size of the dual window is set such that the inner window encloses a target-sized region and the outer window includes its neighboring background. Presence of any linear correlations between the spectral vectors from the IWR and OWR is effectively exploited by CCA. Anomalies are detected if the IWR and OWR spectral vectors are linearly uncorrelated.

However, the presence of background clutter often causes drastic increase in false alarm for the conventional CCA-based anomaly detector. This is because the background clutter can only be fully represented by high order statistics and linear correlations can not exploit the nonlinear structure of the background clutter. Thus, exploitation of high order (nonlinear) correlations of the spectral vectors is highly desirable for spectral anomaly detectors to be able to ignore the background clutter and detect only man-made objects, such as military targets.

In this paper, kernel-based canonical correlation analysis for hyperspectral anomaly detection is proposed that can effectively exploit the high order correlations between the two-channel spectral vectors from the IWR and OWR. In this method, each spectral vector is implicitly transformed into a high dimensional feature space associated with a certain nonlinear mapping. Canonical correlations are then calculated between the transformed two-channel spectral vectors in the feature space which can now exploit the high order correlations due to the nonlinear mapping.

However, due to the very high dimensionality of the feature space calculating the canonical correlations in the feature space is impractical. We use the kernel trick that can convert the CCA expression in the feature space into the form in terms of a nonlinear function (kernel function) of the spectral vectors in a measurement domain. Using the kernel trick we derive the kernel expression equivalent to the CCA in the feature space, which is referred to as kernel canonical correlation analysis (KCCA). The proposed KCCA is applied to the hyperspectral imagery (HYDICE images) to detect anomalies. The ROC curves for the KCCA showed significant improvement in detecting targets over the conventional CCA algorithm.

6233-04, Session 1

Discriminant analysis with nonparametric estimates for subpixel detection of 3D objects

Y. Liu, G. Healey, Univ. of California/Irvine

The large amount of spectral information in hyperspectral imagery allows the accurate detection of subpixel objects. The use of subspace models for targets and backgrounds reduces the dimensionality of the models while retaining information that is used for detection. The non-Gaussian behavior of target and background distribution residuals complicates the development of subspace-based detection statistics.

In this paper, we use discriminant analysis for subspace selection for separating subpixel 3D objects from cluttered backgrounds. The nonparametric estimation of distributions is used to establish the statistical models. Subspaces are evaluated according to their discriminatory power which is measured between distributions of targets and backgrounds that are modeled using the subspaces. Selected subspaces reduce the dimensionality as well as maintain separation between targets and backgrounds. In this context, a likelihood ratio test is used for detection. The detection

algorithm is evaluated for HYDICE images and a number of images simulated using DIRSIG under a variety of conditions. The experimental results demonstrate accurate detection performance on these data sets.

6233-05, Session 1

Hyperspectral detection algorithms: from old ideas to operational concepts to next generation

A. P. Schaum, Naval Research Lab.

Some of the earliest concepts for detecting targets with hyperspectral systems have not been realized in practice in real time systems. Here we review the earlier approaches, most of which were based on simplistic models of hyperspectral clutter. The algorithms employed by the first operational sensors are reviewed and their relationship to the earlier naïve models are discussed. Variants that are likely to be incorporated in the next generation systems are described. Finally, we speculate on the prospects of some futuristic detection methods.

6233-06, Session 1

A classification approach and comparison to other object identification algorithms for hyperspectral imagery

R. R. Mayer, Y. Antoniades, M. M. Baumback, D. Chester, A. Goldstein, D. Haas, S. Henderson, BAE Systems Advanced Information Technologies

Enhancing algorithms for extracting objects from cluttered backgrounds is a principal goal for analysis of hyperpsectral imagery. Search algorithms are especially desired for unfavorable imaging situations when object signature contrast is diminished with respect to cluttered backgrounds. Such adverse conditions for object detection may prevail for data collected at oblique angles and long slant ranges or data gathered for intervening atmospheres between objects and sensors having high humidity, or for sub-pixel object detection. This study adapts and tests a technique from multi-spectral image classification of object detection in hyperspectral imagery. Shrinking the decision surface around the object spectral signature helps extract objects from backgrounds. The object search is achieved through computation of the Mahalanobis distance centered on the average object spectral signature relative to the test pixel spectrum, a whitened Euclidean distance (WED). This restricted object search (WED), the Adaptive Cosine Estimator (ACE), and the matched filter (MF) were applied to independent data sets, specifically to shortwave IR hyperspectral imagery gathered at oblique angles and to visible/near IR data collected at off-nadir angles. To test the robustness of this approach, this study searched for objects using object signatures taken directly from the scene and from statistically transformed object signatures from one time to another. This study found a substantial reduction in the number of false alarms (1 to 2 orders of magnitude) using WED and ACE relative to MF for the two independent data collects. No additional parameters are needed for WED. No spatial filtering is used in this study. No degradation in object detection is observed upon inserting the covariance matrix for the entire image into the Mahalanobis metric relative to using covariance matrix taken from the object.

6233-07, Session 1

Signature evolution with covariance equalization in oblique hyperspectral imagery

R. A. Leathers, A. P. Schaum, T. V. Downes, Naval Research Lab.

Covariance equalization (CE) is a method by which one can predict the change in a target's hyperspectral signature due to changes in sun position and atmospheric conditions. CE produces a linear transformation that relates the target's signatures obtained at disparate times. The transformation is based on the background statistics of a scene imaged at the two times. Although CE was derived under the assumption that the two images cover mostly the same geographic area, it also works well for targets that have moved from one location to another. The CE technique has been previously verified with data from a nadir-viewing visible hyperspectral camera. In this paper, however, we show results from the application of CE to highly oblique hyperspectral SWIR data. Target detection with highly oblique sensors (75 deg. to 80 deg. off-nadir) is far more difficult than with nadir-viewing sensors for several reasons: increased atmospheric optical thickness, which results in lower signal-to-noise and higher adjacency effects; fewer pixels on target; the effects of the nonuniformity of the bi-direction reflectance function of most man-made targets; and the change in pixel size when measurements are taken at different slant ranges. Here, we demonstrate the utility of using CE to improve matched-filter target-detection results under conditions of varying view angle, slant range, altitude, atmospheric conditions, and time of day, and describe the steps necessary to apply CE to such a challenging data set.

6233-08, Session 2

Acceleration of tomographic hyperspectral restoration algorithms

H. C. Schau, Raytheon Co.

Tomographic hyperspectral imagers owe much of their physical simplicity to numerical restoration algorithms for creating the spatial/spectral products from measurements which are often spatial/spectral mixtures. As such, the algorithms must operate on large data sets, and due to their size, are often recursive in nature. Depending of the device, the convergence rate of the recursion can be slow requiring many iterations to form an acceptable solution. We discuss means to accelerate the convergence of the tomographic restoration algorithms. The results are presented for both non-singular and singular kernels and it is shown that acceleration depends strongly on the condition number of the kernel. Acceleration is shown to be dependent on the number of spectral intervals as well as the form of the instrument kernel which is known to be a function of the disperser design. Suitable error metrics for monitoring and stopping the recursion are presented. A discussion of disperser design and acceleration of recursive deconvolution is included.

6233-09, Session 2

Enhancing the resolution of spectral-polarimetric resolution

T. F. Blake, U.S. Air Force; M. E. Goda, S. Cain, Air Force Institute of Technology; K. Jerkatis, Boeing SVS, Inc.

This paper introduces a method for improving the spectral-polarimetric resolution of images by developing a statistical minimization algorithm based on a model of a spectral-polarimetric sensor. The imaging system used in this research is the Advanced Electro-Optical System (AEOS) Spectral Imaging Sensor (ASIS) at the Maui Space Surveillance Complex. ASIS is used to acquire spatially resolved, and adaptive optics corrected, linear polarimetric spectral images of space objects.

The improvement of the linear polarimetric resolution of these images is accomplished by enhancing previously developed Model-Based Spectral Image Deconvolution (MBSID) algorithm. The MBSID algorithm is rederived to take into account linearly polarized spectral images, creating the Model-Based Spectral-Polarimetric Image Deconvolution (MBSPID) algorithm. As with the MBSID algorithm, the MBSPID algorithm can be used for any spectral-polarimetric sensor, but needs a sensor to model. For this discussion, ASIS will be the sensor used.

The paper reviews the development of the MBSID algorithm and the model development of ASIS used with the algorithm. The discussion then turns to the addition of the linear polarimetry and how the algorithm and model changes. Simulated images of polarized stars are used to show the benefit of the model based image processing. The paper also demonstrates how understanding the sensor model can not only improve the spectral-polarimetric image, but can lead to better utilization of the sensor. Finally, the paper discusses how the utilization of both a sensor model and processing algorithms during the sensor design phase can lead to a more efficient system than one designed independently.

6233-10, Session 2

Restoration and resolution enhancement of hyperspectral imagery

A. Umaña-Díaz, M. Vélez-Reyes, Univ. de Puerto Rico Mayagüez

Proposed satellite-based hyperspectral systems for military and civil surveillance applications have competing requirements of broad swath width and high spatial resolution. As a result, many natural and man-made targets of interest are spatially unresolved (subpixel) which necessitates the development of algorithms to perform subpixel object recognition. However, the quality of the retrieved information for full pixel and subpixel object recognition is affected by a host of confounding physical processes: natural variability of spectral signatures, environmental variations, and degradation introduced by the sensing system and sensor noise. This paper will present some preliminary work in the development of hyperspectral image restoration algorithms that try to remove bluring effects in the spatial and spectral domains and its effects in classification performance.

6233-11, Session 3

Multispectral change detection for finding small targets using MANTIS-3T data

J. J. Dirbas, P. Henderson, R. W. Fries, PAR Government Systems Corp.; A. R. Lovett, Naval Air Systems Command

PAR Government Systems Corporation (PAR), with support from Naval Air Weapons Center (NAWC) Patuxent River, has deployed the turret mounted Mission Adaptable Narrowband Tunable Imaging System (MANTIS-3T) and collected nearly 300 GBytes of multispectral data over mine-like targets in a desert environment in support of mine counter measures (MCM), intelligence, surveillance, and reconnaissance study applications. Data collected includes spectral imagery of roadside locations with and without mine like objects. Spectral processing algorithms such as RX and SEM have demonstrated success with hyperspectral data when searching for large targets. However, as target size decreases relative to sensor resolution, false alarms increase and performance declines. This trend can be countered by using imagery of a given location collected at different times thus adding a temporal dimension to the processing. Detection of recently placed mine-like objects or roadside targets is an application of these techniques. A Multispectral change detection algorithm has been developed and used to process the multispectral desert data collected with MANTIS-3T. Performance results and processing difficulties are reported.

6233-12, Session 3

Vehicle tracking with multitemporal hyperspectral imagery

J. P. Kerekes, M. Muldowney, K. Strakerjan, L. E. Smith, Rochester Institute of Technology

Hyperspectral imagery has the potential of capturing spectral features of interest that can be used to differentiate among similar materials. While hyperspectral imaging has been demonstrated to provide data that enable classification of relatively broad categories, there remain open questions as to how fine of discrimination is possible. A particularly interesting question is to explore the extent possible that spectral features exist in the surface reflectance of ordinary civilian vehicles that would enable unique tracking of the vehicle across repeated hyperspectral images in a cluttered urban area.

To begin to explore this question a vehicle tracking experiment was conducted in the summer of 2005 on the Rochester Institute of Technology (RIT) campus in Rochester, New York. Several volunteer vehicles were moved around campus at specific times coordinated with overflights of RIT's airborne Modular Imaging Spectrometer Instrument (MISI). MISI collected sequential images of the campus in 70 spectral channels from 0.4 to 1.0 microns with a ground resolution of approximately 2.5 meters. Ground truth spectra and photographs were collected for the vehicles as well.

These data are being analyzed to determine the ability to uniquely associate a vehicle in one image with its location in a subsequent image. Preliminary results with simple processing schemes indicate vehicles with different paints can be discerned, but vehicles with similar paints cannot. Current efforts are investigating more sophisticated processing approaches as well as to explore predicted performance for variations in scene and sensor parameters through an analytical performance prediction model. Results based on both the empirical analysis of the experimental data and the model predictions will be presented.

6233-14, Session 3

Real-time cloud detection for remotely sensed data with a small number of bands

S. P. Hagerty, J. Gaines, Ball Aerospace & Technologies Corp.

One of the key requirements of real-time processing systems for remote sensors is the ability to accurately and automatically geo-locate events. This capability often relies on the ability to find control points to feed into a registration-based geo-location algorithm. Clouds can make the choice of control points difficult. If each pixel in a given image can be identified as cloudy or clear, the geo-location algorithm can limit the control point selection to clear pixels, thereby improving registration accuracy. This paper discusses the feasibility of providing a real-time cloud mask as a stage in the pre-processing pipeline for remote sensing algorithm suites. The effort investigated statistical, spatial and texture-based aproaches. This paper discusses these approaches and performance results obtained on real remote sensing data. Most cloud masking algorithms rely on a large number of spectral bands for good results, e.g., MODIS. With our sensor, only three bands are available, so this work focuses on alternative algorithms that will provide good performance with a small number of spectral bands. The spatial and texture-based approaches did not, in general, exhibit good performance, so most of the paper focuses on the statistical-based classification method. Images from three daytime remote sensing collects were anlayzed to determine features that best separate pixels into cloudy and clear classes. A Bayes classifier was then applied to feature vectors computed for each pixel to generate a binary cloud mask. Initial results are very promising and show good accuracy over a variety of terrain types including mountains, desert, and coastline.

6233-15, Session 3

Mean-class hyperspectral propagation

S. T. Kacenjar, D. M. Pustai, D. A. Bennett, Lockheed Martin Corp.

In this paper, we present a new method called mean-class propagation that employs clusters of similar class materials in hyperspectral scenes to preserve scene spectral clutter information. This method allows for better insight on how environmental conditions alter the statistical properties of the measured scene clutter. With this method, hyperspectral scene data can be processed faster and more robust spectral matched filters can be formulated to potentially improve detection probability.

In contrast, pixel-based propagation methods offer high fidelity in scene rendition of hyperspectral data; however, the inherent drawbacks hide certain physical effects and increases computation time. To this end, we compare a pixel-based method with our mean-class propagation method in terms of two performance measurands, computation time and detection limits, wherein the lower limits of detection will be defined.

6233-16, Session 4

Hyperspectral image analysis using noise-adjusted principal component transform

Q. Du, Mississippi State Univ.

The Noise-Adjusted Principal Components (NAPC) transform, or Maximum Noise Fraction (MNF) transform, was proposed in the late 1980's. Since then it has received considerable interest in remote sensing community. Its basic idea is to reorganize the data such that principal components are ordered in terms of signal to noise ratio (SNR), instead of variance as used in ordinary principal components analysis (PCA). The NAPC transform is very useful in multi-dimensional image analysis, because the principal component images are ranked in the order of SNR, which is directly related to image quality. So object information can be better compacted into the first several principal components.

This paper reviews the fundamental concepts of the NAPC transform and discusses its practical implementation issues, such as how to get accurate noise estimation, which is the key to the success of its implementation. Five applications of the NAPC transform in hyperspectral image analysis are presented, which include: image interpretation, visualization, image compression, image classification, and estimation of the number of signals. The spaceborne Hyperion data and airborne HYDICE data are used for performance demonstration, which show that the NAPC transform can better compact the object information into major principal components. As a result, the performance of the following data analysis can be significantly improved.

6233-17, Session 4

Using spatial filtering to improve spectral distribution invariants

C. Kuan, G. Healey, Univ. of California/Irvine

We show that moment invariants of spatially filtered multiband images are invariant to linear coordinate transforms. These transforms account for illumination and atmospheric variation in airborne and space-based hyperspectral images. The moment invariants are applied to image region classification and recognition. The Fisher discriminant is used for band selection in conjunction with the invariants. Different spatial filters on the bands of the spectral image are used to enhance performance. We demonstrate the approach with classification, recognition, and change detection experiments on hyperspectral image regions acquired under different illumination and atmospheric conditions.

6233-18, Session 4

Sparse linear filters for detection and classification in hyperspectral imagery

J. Theiler, S. J. Perkins, Los Alamos National Lab.; K. Glocer, Los Alamos National Lab. and Univ. of California/Santa Cruz

We investigate the use of convex optimization to identify sparse linear filters in hyperspectral imagery. A linear filter is sparse if a large fraction of its coefficients are zero. A sparse linear filter can be advantageous because it only needs to access a subset of the available spectral channels, and it can be applied to high-dimensional data more cheaply than a standard linear detector. Finding good sparse filters is nontrivial because there is a combinatorically large number of discrete possibilities from which to choose the optimal subset of nonzero coefficients. But, by converting the optimality criterion into a convex loss function, and by employing an L1 regularizer, one can obtain sparse solutions that are globally optimal. We investigate the performance of these sparse filters as a function of their sparsity, and compare the convex optimization approach with more traditional alternatives for feature selection. The methodology is applied both to the adaptive matched filter for weak signal detection, and to the Fisher linear discriminant for terrain categorization.

6233-19, Session 4

Classification of hyperspectral spatial/spectral patterns using Gaussian Markov random field models

H. A. Smartt, Sandia National Labs. and Univ. of New Mexico; J. S. Tyo, The Univ. of New Mexico

Hyperspectral imaging sensors gather reflected radiation from the ground in hundreds of contiguous spectral bands, allowing remote material identification. Most algorithms for identifying materials characterize the materials by spectral information only, ignoring potentially valuable spatial relationships. There has been interest recently in the simultaneous use of spatial and spectral information in order to improve the performance of algorithms. Spectral Gaussian Markov Random Field (GMRF) analyses have been proposed in anomaly detection and pattern classification applications.

This paper investigates the use of integrated spatial and spectral information for characterizing patterns in hyperspectral images. We examine the specific situation where a set of pixels has resolution such that it contains spatial patterns of mixed pixels. We use a spectral vector GMRF to model the contributions to a target pixel from neighboring pixels. We have shown that at the resolution of interest, the GMRF model can successfully classify several different patterns in both simulated and real hyperspectral data, including regularly placed aircraft on a tarmac, multiple classes of camouflage patterns, and residential areas. The proposed method is relevant to a number of hyperspectral applications including scene classification and target ID.

6233-20, Session 4

Sample spectral correlation-based measures for subpixels and mixed pixels in real hyperspectral imagery

W. Liu, C. Chang, Univ. of Maryland/Baltimore County

Many spectral measures used for material discrimination and identification in hyperspectral imagery are performed on a pixel-level basis. This paper demonstrates that on many occasions a pixel level-based spectral measure is generally not effective when it is applied to real data for discrimination and identification because it does not take into account the sample spectral correlation (SSC), specifically for the cases of mixed pixels or subpixels. In order to address this issue, two approaches, referred to as a priori sample spectral correlation (PR-SSC) and a posteriori SSC (PS-SSC) are developed to account for spectral variability within real data to achieve better discrimination and identification of mixed pixels and subpixels. While the former derives a priori hyperspectral measures which use the orthogonal subspace projection (OSP) to eliminate interfering effects caused by undesired signatures, the latter results in a posteriori hyperspectral measures that include sample covariance/correlation matrix as a posteriori information to increase ability in discrimination and identification. Interestingly, some well-known pixel-level spectral measures such as Euclidean distance (ED) and spectral angle mapper (SAM) can be shown to be special cases of the proposed PR-SSC and PS-SSC hyperspectral measures.

6233-21, Session 4

A new 3D receiver operating characteristic curve for detection performance analysis

H. Ren, National Central Univ. (Taiwan)

Target detection for remotely sensed imagery has been invasively researched for decades. Many detection algorithms are designed and claimed to be outperform others. In order to make an objective comparison, two issues need to be solved. The first one is to have standardized data sets with accurate ground truth, and the second one is to use objective performance analysis techniques. The Receiver Operating Characteristic (ROC) curve is one of the most recognized tools for detection performance analysis. It is based on binary hypothesis test approach. First it constructs two hypothesis distributions (null and alternative hypotheses) and then draws the ROC curve by calculating all the possible detection probability and false-alarm probability pairs. The larger area under the curve means the better detection performance of the algorithm. But one point is usually missing. In ROC analysis, the alternative

hypothesis means target exists, but we seldom discuss how much target presents. In this paper, we include target abundance as the third dimension to form 3-D ROC. The proposed technique can be used to analyze the performance of detection algorithms or the sensor instruments from the different point of views. It can perform the detection probability versus false-alarm probability test as the original ROC, and it can also be use to estimate the minimum target abundance the algorithm can detect.

6233-22, Session 4

An algorithm for wavelength calibration in hyperspectral imaging camera

E. Lo, Susquehanna Univ.; A. W. Fountain III, U.S. Military Academy

The wavelength of the spectral bands of a pixel from a hyperspectral imaging camera that uses a Prism-Grating-Prism system is not automatically known, but the abscissa of the spectral bands are known. In order to determine the exact position of features in spectra, it is necessary to have an algorithm to accurately define the abscissa in terms of the wavelength. A simple linear regression equation for wavelength versus abscissa can be obtained by fitting the abscissa of the peaks of an absorbance pixel with corresponding known wavelengths. To get an accurate regression equation to determine the wavelength for all the pixels in a cube, the regression equations obtained from each pixel in the cube should not be significantly different statistically. In our experiment the pixels in the cube drift as a function of the spatial domain so the pixels do not form a random sample. The drift is much more significant in one of the spatial dimension than the other spatial dimension. An algorithm to detrend the pixels (remove the drift from the pixels) in an iterative mode will be presented.

6233-23, Session 5

Pseudo imaging

R. J. Nelson, J. M. Mooney, Solid State Scientific Corp.; W. S. Ewing, Air Force Research Lab.

The detection, determination of location, and identification of unknown and uncued energetic events within a large field of view represents a common operational requirement for many staring sensors.The traditional imaging approach involves forming an image of an extended scene and then rejecting background clutter. However, some important targets can be limited to a class of energetic, transient, point-like events, such as explosions, that embed key discriminants within their emitted temporally varying spectra; for such events it is possible to create an alternative sensor architecture tuned specifically to the objects of interest. The resulting sensor operation, called pseudo imaging, includes: optical components designed to encode the scene information such that the spectral-temporal signature from the event and its location are easily derived; and signal processing intrinsic to the sensor to declare the presence of an event, locate the event, extract the event spectral-temporal signature, and match the signature to a library in order to identify the event.

This treatise defines pseudo imaging, including formal specifications and requirements. Two examples of pseudo imaging sensors are presented: a sensor based on a spinning prism, and a sensor based on a novel optical component called the Crossed Dispersion Prism. The sensors are described, including how the sensors fulfill the definition of pseudo imaging, and measured data is presented to demonstrate their functionality.

6233-24, Session 5

Design of an LWIR snapshot imaging spectropolarimeter

R. W. Aumiller, N. Hagen, E. L. Dereniak, College of Optical Sciences/The Univ. of Arizona; R. E. Sampson, I Technology Applications

This publication presents the design of an imaging spectropolarimeter for use in the 8 to 12 micron, longwave infrared region. The design is based on the Computed Tomographic Imaging Spectrometer (CTIS) and will allow the collection of both spectral and polarization data from multiple spatial locations in a single integration period.

6233-25, Session 5

Compact CMOS multispectral/polarimetric camera

B. E. Catanzaro, CFE Services; J. M. Lorenz, M. S. Dombrowski, Surface Optics Corp.

A novel, compact visible multispectral, polarimetric camera has been developed. The prototype is capable of megapixel imaging with sixteen wavebands and three polarimetric images. The entire system encompasses a volume less than 125 mm x 100 mm x 75 mm. The system is based on commercial megapixel class CMOS sensors and incorporates real time processing of hyperspectral cube data using a proprietary processor system based on state of the art FPGA technology. System performance and sample cubes are discussed.

6233-26, Session 5

Performance and application of a very high-speed 2-12 μm ultraspectral FTIR imager

M. S. Dombrowski, M. Szczesniak, M. T. Beecroft, J. P. Ferguson, Surface Optics Corp.; B. E. Catanzaro, CFE Services

As an offshoot of hyperspectral imaging, which typically acquires tens to slightly more than 100 spectral bands, ultraspectral imaging, with typically more than 1000 bands, provides the ability to use molecular or atomic lines to identify surface or airborne contaminants. Surface Optics Corporation has developed a very high-speed Fourier Transform Infrared (FTIR) imaging system. This system operates from 2 um to 12 um, collecting 128 x 128 images at up to 10,000 frames-per-second. The high-speed infrared imager is able to synchronize to almost any FTIR that provides at least mirror direction and laser clock signals. FTIRs rarely produce a constant scan speed, due to the need to physically move a mirror or other optical device to introduce an optical path difference between two beams. The imager is able to track scan speed jitter, as well as changes in position of the zero path difference (ZPD) position, and perform real-time averaging if desired. Total acquisition time is dependent on the return stroke speed of the FTIR, but 16 cm-1 (1024 point) spectral imagery can be generated in less than 1/5 second, with 2 cm-1 (8192 point) spectral imagery taking proportionately longer. The imager is currently configured with X-Y position stages to investigate surface chemistry of varied objects. Details of the optical design, focal plane array, and electronics that allow this high-speed FTIR imager to function are presented. Results of using the imager for several applications are also presented.

6233-27, Session 5

Object discrimination and optical performance of a real-time 2-5 μm hyperspectral imager

M. S. Dombrowski, R. L. Dombrowski, Surface Optics Corp.; B. E. Catanzaro, CFE Services; E. Hillenbrand, Naval Surface Warfare Ctr.

Hyperspectral imaging in the SWIR/MWIR provides a wealth of information for object discrimination and tracking. Key to allowing such a system to operate in a wide range of applications is the ability to generate and process hyperspectral imagery in real time. A 2 - 5 um hyperspectral imager, capable of generating and processing complete hyperspectral image cubes at up to 15 cubes-per-second, has been developed and is undergoing testing. Using a novel prism-based hyperspectral imaging approach together with fast F/1.8 optics allows this system to provide both high speed and high sensitivity. All spectral bands are collected si-

multaneously ensuring spectral purity. The system achieves line-imaging rates of over 4,000 lines-per-second. Data generated by the compact imaging head flows to an equally compact hyperspectral image processor which calibrates the raw imagery and then implements varied spectral processing algorithms to identify and differentiate targets of interest. The complete system, excluding the host computer, measures only 23" x 7" x 9". Details of the optical design and performance, including examples of real-time object discrimination and application to various real-time tasks, are discussed

6233-28, Session 5

Innovative manufacturing and test technologies

L. E. Comstock, Corning NetOptix; P. G. Dewa, M. M. Dunn, Corning Tropel Corp.

Corning has developed a number of manufacturing and test techniques to meet the challenging requirements of imaging hyperspectral optical systems. These processes have been developed for applications in the short-wave visible through long-wave IR wavelengths. Optical designs for these imaging systems are typically Offner or Dyson configurations, where the critical optical components are powered gratings and slits. Precision alignment, system athermalization, and harsh environmental requirements, for these systems drive system level performance and production viability.

This paper will present the results of these techniques including all aluminum gratings and slits, innovative grating profiles, snap together self-aligning mechanical designs, and visible test techniques for IR systems.

6233-29, Session 5

Image registration for Fizeau Fourier transform imaging spectroscopy

S. T. Thurman, J. R. Fienup, Univ. of Rochester

Fourier transform imaging spectroscopy can be performed with both Michelson and Fizeau imaging interferometers, by recording a series of images with various optical path differences between subapertures of the optical system, and post-processing. In both cases, the quality of the spectral data is affected by misregistration of the raw intensity measurements. Each system has design tradeoffs that can be used to facilitate registration of the raw intensity measurements. One approach for a Michelson system is to use a four-port interferometer design that requires two detector arrays. A Fizeau system possesses unique degrees of freedom that can be used to facilitate image registration without further complication of the system design and requires only one detector array. We will discuss system differences and demonstrate the Fizeau registration technique through computer simulation for misregistrations due to image shift.

6233-30, Session 5

Analyzing sensors with highly overlapping spectral bands

Z. Wang, J. S. Tyo, M. M. Hayat, The Univ. of New Mexico

Most hyperspectral data is interpreted using a geometric model where the band numbers are assigned as labels of the coordinates of a Cartesian hyperspace. The conventional spectral system model allows overlaps between spectral responsivities of different bands, but their influence on the output data is not carefully analyzed because such overlaps are usually small. A new class of adaptive spectral sensor has been proposed that is based on electrically tunable quantum-dot based photodectors. For these detectors, we must deal with highly overlapping bands, and the influence of this overlap on the image processing result cannot be ignored. For convenience of analysis, a generalized geometry-based model is provided for spectral sensors with arbitrary spectral responsivities. In this model, the spectral responsivities of a sensor span its sensor space. The spectral imaging process is shown to represent a projection of the scene spectra onto sensor space. The projected vector, which is the least-square reconstruction of the scene vector, contains the available information for image processing. The photoresponse is the coefficient of this projection with a particular basis of sensor space and processing the photoresponse is indirectly processing the projected vector. With this model, we find that image processing algorithms based on the second-order statistics of the data can be applied directly to the photoresponse of such sensors. However, for those algorithms based on the first-order statistics, a pre-processing step must be used first to remove the influence of the overlap. Simulation and discussion shows that this model can facilitate data processing and interpretation.

6233-31, Session 6

The use of remotely sensed data and innovative modeling to improve hurricane prediction

R. M. Atlas, NOAA Atlantic Oceanographic and Meteorological Lab.

Abstract not available

6233-32, Session 6

U.S. Environmental Protection Agency civil airborne rapid needs assessment efforts in the aftermath of Hurricanes Katrina and Rita

M. J. Thomas, U.S. Environmental Protection Agency Region VII

Abstract not available

6233-34, Session 7

Comparisons between spectral quality metrics and analyst performance in hyperspectral target detection

J. P. Kerekes, B. Leahy, D. W. Messinger, Rochester Institute of Technology; R. E. Simmons, ITT Industries

Quantitative methods to assess or predict the quality of a spectral image continue to be the subject of a number of current research activities. An accepted methodology would be highly desirable for use in data collection tasking or data archive searching in ways analogous to the current prediction of image quality through the National Imagery Interpretation Rating Scale (NIIRS) using the General Image Quality Equation (GIQE). A number of approaches to the estimation of quality of a spectral image have been published, but most capture only the performance of automated algorithms applied to the spectral data. One recently introduced metric, however, the General Spectral Utility Metric (GSUM), provides for a framework to combine the performance from the spectral aspects together with the spatial aspects. In particular, this framework allows the metric to capture the utility of a spectral image resulting when the human analyst is included in the process. This is important since nearly all hyperspectral imagery analysis procedures include an analyst.

To investigate the relationships between the GSUM (and related spectral metrics) and achievable analysis task performance from volunteer human analysts in conjunction with the automated results, simulated images are generated and processed in a blind test. The performance achieved by the analysts is then compared to predictions made from various spectral quality metrics to determine how well the metrics function.

The task selected is one of finding a specific vehicle in a cluttered environment using a detection map produced from the hyperspectral image along with a panchromatic rendition of the image. Various combinations of spatial resolution, number of spectral bands, and signal-to-noise ratios are investigated as part of the effort.

6233-35, Session 7

Perceptual display strategies of hyperspectral imagery based on PCA and ICA

H. Zhang, D. W. Messinger, E. Montag, Rochester Institute of Technology

Hyper-Spectral imagers that can measure spectra at more than 200 narrow, contiguous bands have been developed in recent years. With the increasing number of bands, the remotely sensed hyperspectral imagery provides finer spectral resolution, yet presents challenges for data visualization techniques for display of the information content of such datasets. Color, as one of the attributes to display information, may be used effectively for more efficient data presentation and interpretation. This study investigated appropriate methodologies for displaying hyperspectral imagery based on knowledge of human color vision as applied to Hyperion data.

Principal Component Analysis (PCA) and Independent Component Analysis (ICA) were used to reduce the data dimensionality in order to make the data more amenable to visualization in three-dimensional color space. In addition, these two methods were chosen because of their underlying relationships to the opponent color model of human color perception.

PCA and ICA-based visualization strategies were then explored by mapping the first three PC or IC to several opponent color spaces including CIELAB, HSV, YCbCr, and YIQ. The gray world assumption, which states that given an image with sufficient amount of color variations, the average color should be gray, was used to set the mapping origins. The rendered images are well color balanced and can offer a first look capability or initial classification for a wide variety of spectral scenes.

The usefulness of the strategies may be evaluated and compared with other visualization techniques found in the literature by psychophysical experiments.

6233-36, Session 7

Spectral obervations of SO2 plumes

M. Porter, R. C. Olsen, R. M. Harkins, Naval Postgraduate School

Spectral imagery was collected at a coal-fired power plant in St Johns, Arizona in April, 2005. The LINUS spectrometer sampled the plume over a wavelength range from 2950-3100 Angstroms, with a resolution of 0.83 Angstroms. Data were taken at a distance 537 m. Smokestack monitors indicated a concentration of 100-245 ppm. Analysis of the spectra was done by comparison to the clear sky background showed agreement within a factor of 2 of the calibrated value.

6233-37, Session 7

Image data transfer over the Internet protocol for air quality studies

C. J. Wong, Univ. Sains Malaysia (Malaysia)

Modern digital technology allows image data transfer over the internet protocol, which provides real time observation and more frequent air quality studies can be carried at multi locational simultaneously. The objective of this study is to evaluate the suitability of using internet protocol camera to transfer image data, and then these data were analysed using a developed algorithm to determine air quality information. The concentrations of particulate matter of size less than 10 micron (PM10) were collected simultaneously with the image data acquisitions. The atmospheric reflectance components were subtracted from their corresponding recorded radiance values for algorithm regression analysis. The proposed algorithm produced high correlation coefficient (R) and low root-mean square error (RMS) values. The efficiency of the present algorithm, in comparison to other forms of algorithm, was also investigated. Based on the values of the correlation coefficient and root-mean-square deviation, the proposed algorithm is considered superior. The accuracy of using IP camera data was compared with a normal digital camera, Kodak DC290 data in this study. This preliminary study gave promising results of air quality studies over USM campus by using internet protocol data.

6233-38, Session 8

Haralick texture features expanded into the spectral domain

A. M. Puetz, R. C. Olsen, Naval Postgraduate School

Haralick et. al. described a technique for computing texture features based on gray-level spatial dependencies using a Gray Level Co-Occurrence Matrix (GLCM). A method to calculate 'spectral texture' is modeled on Haralick's texture features. This spectral texture method uses spectral-similarity spatial dependencies (rather than gray-level spatial dependencies).

The traditional GLCM process quantizes a gray-scale image into a small number of discrete gray-level bins. The number and arrangement of spatially co-occurring gray-levels in an image is then statistically analyzed. The output of the traditional GLCM process is a gray-scale image with values corresponding to intensity of the statistical measure.

In the Spectral Texture method, a spectral image is quantized based on discrete spectral angle ranges. Each pixel in the image is compared to an exemplar spectrum, and a quantized image is created in which pixel values correspond to a spectral similarity value. Statistics are calculated on spatially co-occurring spectral-similarity values.

Comparisons to the traditional GLCM process will be made, and possible uses of Spectral Texture Features will be discussed.

6233-39, Session 8

Change detection in hyperspectral imagery using temporal principal components

V. Ortiz-Rivera, M. Vélez-Reyes, Univ. de Puerto Rico Mayagüez; B. Roysam, Rensselaer Polytechnic Institute

Change detection is the process of automatically identifying and analyzing regions that have undergone spatial or spectral changes from multi temporal images. Detecting and representing change provides valuable information of the possible transformations a given scene has suffered over time. Change detection in sequences of hyperspectral images is complicated by the fact that change can occur in the temporal and/or spectral domains. This work studies the use of Temporal Principal Component Analysis (TPCA) for change detection in multi/hyperspectral images. TPCA was compared against other methods such as Image Differencing and Conventional Principal Component Analysis. Hyperspectral imagery from different sensors showing different scenarios was used to test and validate the methods presented in this study. The performances of the algorithms are presented in terms of false alarms and missed changes. Overall results showed that the performance of TPCA was the best.

6233-40, Session 8

Exploration of virtual dimensionality in hyperspectral image analysis

C. Chang, Univ. of Maryland/Baltimore County

Virtual dimensionality (VD) is a new concept which was developed to estimate the number of spectrally distinct signatures present in hyperspectral image data. Unlike intrinsic dimensionality which is abstract and of theoretical interest, the VD is a very useful and practical notion, and can be found by Neyman Pearson-based eigen-thresholding methods. Unfortunately, its utility in hyperspectral data exploitation has yet to be explored. This chapter presents several applications to which the VD is applied successfully. Since the VD is derived from a binary hypothesis testing problem for each spectral band, it can be used for band selection. When the test fails for a band, it indicates that there is a signal source in that

particular band which must be selected. By the same token it can be further used for dimensionality reduction. For unsupervised target detection and classification, the VD can be used to determine how many unwanted signal sources present in the image data so that they can be eliminated prior to detection and classification. For endmember extraction, the VD provides a good estimate of the number of endmembers needed to be extracted. For principal components analysis (PCA) or independent component analysis (ICA), the VD helps to determine the number of principal components or independent components are required for exploitation such as detection, classification, compression, etc. All these applications are justified by experiments.

6233-41, Session 8

Applications of independent component analysis (ICA) to abundance quantification for hyperspectral imagery

J. Wang, C. Chang, Univ. of Maryland/Baltimore County

Independent component analysis (ICA) has shown success in many applications. New applications are yet to be explored. This paper investigates new applications of the ICA in endmember extraction and abundance quantification for hyperspectral imagery. One of major issues in the use of the ICA is determination of the number of independent components (ICs), p required to be generated for endmember extraction. A recently developed new concept, virtual dimensionality (VD) is used to estimate such p. Another issue is how to select p ICs for endmember extraction and abundance quantification. Since the ICA generally uses randomly generated initial projection vectors to produce ICs, these ICs are not arranged in order as the PCA does for its principal components according to the magnitudes of eigenvalues. To resolve this difficulty, this paper introduces a new idea of IC prioritization and further develops algorithms to select an appropriate set of p ICA-generated ICs. Most importantly, unlike many endmember extraction algorithms (EEAs) which cannot perform abundance quantification, the proposed ICA approach can accomplish both simultaneously.

6233-42, Session 8

PDE methods for hyperspectral image processing

J. M. Duarte-Carvajalino, M. Vélez-Reyes, P. Castillo, Univ. de Puerto Rico Mayagüez

For two decades, techniques based on Partial Differential Equations (PDEs) have been used in image processing for image segmentation, restoration, smoothing and multiscale image representation. Among these techniques, parabolic PDEs have found a lot of attention for image smoothing and image restoration purposes. Image smoothing by parabolic PDEs can be seen as a continuous transformation of the original image into a space of progressively smoother images identified by the “scale” or level of image smoothing, in terms of pixel resolution. However, the semantically meaningful objects in an image can be of any size, that is, they can be located at different image scales, in the continuum scale-space generated by the PDE. The adequate selection of an image scale smoothes out undesirable variability that at lower scales constitute a source of error in segmentation and classification algorithms. This paper presents a framework for hyperspectral image processing using PDE methods. We illustrate some of our ideas by hyperspectral image smoothing using nonlinear diffusion as an image enhancement pre-processor for image classification and study its effects in classification performance using simulated hyperspectral imagery and the Indian Pines AVIRIS image.

6233-43, Session 8

Commodity cluster and hardware-based massively parallel implementations of algorithms for hyperspectral analysis

A. J. Plaza, Univ. de Extremadura (Spain)

The incorporation of hyperspectral sensors aboard airborne/satellite platforms is currently producing a nearly continual stream of multidimensional data, and this high data volume has quickly introduced new processing challenges. In particular, the price paid for the wealth of spatial and spectral information available from hyperspectral sensors is the enormous amounts of data that they generate. Several applications exist, however, where having the desired information calculated quickly enough for practical use is highly desirable, including environmental modeling and assessment, risk/hazard prevention and response including wild land fire tracking, biological threat detection and monitoring of oil spills and other types of chemical contamination. Fast performance is particularly crucial in defense/security applications which utilize hyper/ultraspectral data, where a commonly pursued goal is detection of full-pixel or sub-pixel targets, often associated to hostile weaponry, camouflage, concealment, and decoys. This paper describes our experience in the development of fast, parallel data processing techniques able to transform the massive amount of information currently produced by hyperspectral sensors into scientific understanding in valid response times. Techniques for near real-time information extraction and mining from very large data archives are presented and evaluated in the context of different applications. Also, real-time algorithms for onboard hyperspectral data analysis and compression are discussed. Techniques include four classes of algorithms: (1) classification and segmentation; (2) target/anomaly detection; (3) endmember extraction; and (4) data compression. Two high-performance computing architectures are used in this work: Thunderhead, a massively parallel Beowulf cluster located at NASA’s Goddard Space Flight Center which is used in this work for near real-time information extraction and mining from sensor data repositories, and a Xilinx Virtex-II field programmable gate array (FPGA) used for real-time data processing. Our quantitative and comparative assessment of more than 20 different parallel techniques (in terms of both parallel efficiency and performance accuracy) may help analysts in selection of algorithms for specific applications.

6233-44, Session 8

An algorithm for computing partial pixel in hyperspectral imaging camera calibration

E. Lo, Susquehanna Univ.; A. W. Fountain III, U.S. Military Academy

In wavelength calibration of a hyperspectral imaging camera, it is necessary to obtain an accurate estimate of the partial pixel of an absorbance spectrum. Current algorithms for determining the partial pixel are based on least-squared models for fixed order and fixed number of data points in which the number of data points has to be odd. An efficient algorithm for determining the partial pixels based on linear regression models for variable order and variable number of data points in which the number of data points may be odd or even will be developed and justified. The order and number of points to be used for each spectral band is selected by statistically comparing the sum of squared errors of the reduced model with that for the full model. The regression parameters can be obtained in an efficient way by exploiting the uniform spacing in the spectral bands. The first derivative and second derivative at each spectral band are obtained using the resulting linear regression model for that spectral band. The critical points and inflection points of the spectrum are estimated from these derivatives using polynomial interpolation in which the interpolation is implemented in Newton’s divided differences. The critical points and inflection points are used in the estimation of the partial pixel. Absorbance spectra from the wavelength calibration of a hyperspectral imaging camera will be used in the numerical experiments.

6233-45, Session 9

Lessons from three years of hyperspectral data from the atmospheric infrared sounder (AIRS) on the EOS AQUA

H. H. Aumann, D. Elliott, Jet Propulsion Lab.

AIRS is the first of the hyperspectral infrared sounders in support of weather forecasting and climate research. AIRS, which was launched into polar 705 km altitude orbit on the EOS Aqua spacecraft on May 4, 2002, covers the 3.7 to 15.4 micron region of the thermal infrared spectrum with spectral resolution of * * * * =1200. Since the start of routine data gathering in September 2002 AIRS has returned 3.7 million spectra of the upwelling radiance each day. The operational assimilation of AIRS data into the weather forecast by NOAA, ECMWF and UKMetop have shown positive forecast impact.

The AIRS design, a grating array spectrometer with no moving parts, was selected for is exceptional radiometric qualities. Its demonstrated radiometric accuracy at the 100 mK level, better than 10 mK/year radiometric calibration stability and spectral response function (SRF) stability of 1 ppm/year show that AIRS spectral radiances are approaching the level of performance expected from climate quality data and establish the accuracy and stability of radiometric calibration expected from the new generation of hyper-spectral sounders.

Lessons from the AIRS data include the identification of very accurate existing products, particularly the RTGSST produced by NOAA/NCEP and the global temperature profile over ocean from ECMWF. An important lesson from AIRS data relates to spatial scene variability.

The much larger than expected spatial non-uniformity of land and ocean scenes due to spatial variability of water vapor and surface emissivity, shows the criticality of achieving 99% footprint overlap over the full spectral range of future hyperspectral sounders and the importance of much higher spatial resolution than the AIRS 15 km footprints. The AIRS grating array design can be extended to achieve 1 km spatial resolution with AIRS spectral resolution and radiometric sensitivity from a 1000 km altitude orbit. This would open new fields for the remote sensing of minor gases and surface characterization.

6233-46, Session 9

Improved soundings and error estimates using AIRS/AMSU data

J. Susskind, NASA Goddard Space Flight Ctr.; R. M. Atlas, NOAA Atlantic Oceanographic and Meteorological Lab.

AIRS/AMSU is a state of the art high spectral resolution IR/MW sounding system launched on EOS Aqua in May 2002. The primary purposes of the AIRS/AMSU are for use in improving numerical weather prediction and the study of climate variability and trends. The Goddard DAAC has been analyzing AIRS/AMSU data using the AIRS Science Team Version 4 retrieval algorithm since April 2005. Further improvements in retrieval methodology are being made towards development of a Version 5 retrieval algorithm to be made operational at the Goddard DAAC in mid 2006. Considerable improvement is being made with regard to error estimates and quality control of both the derived soundings and the clear column radiances used to generate them. Improved error estimates and quality control are significant for both data assimilation and climate purposes. The improvements in sounding methodology will be described. Results will be shown demonstrating the accuracy of soundings and clear column radiances and their error estimates, as well as the characteristics of the new quality control algorithm. Results of a forecast impact study using this data will also be presented.

6233-47, Session 9

Importance of the AIRS shortwave sounding channels

J. Susskind, NASA Goddard Space Flight Ctr.; L. Kouvaris, Science Applications International Corp.

AIRS contains 2376 high spectral resolution channels between 650 cm-1 and 2650 cm-1, encompassing both the 15 micron and 4.2 micron CO2 sounding bands. Use of temperature sounding channels in the 15 micron CO2 band has considerable heritage in infra-red remote sensing. Channels in the 4.2 micron band have potential advantages for temperature sounding purposes because they are essentially insensitive to absorption by water vapor and ozone, and also have considerably sharper temperature sounding weighting functions than do the 15 micron sounding channels. Potential drawbacks for use of these channels arise from effects on the observed radiances of solar radiation reflected by the surface and clouds, as well as effects on non-local thermodynamic equilibrium. These are of no practical consequences, however, when properly accounted for.

We show results of experiments performing soundings utilizing different spectral regions, conducted with the basic AIRS Science Team retrieval algorithm. Experiments were performed using channels within the entire AIRS spectral coverage; within only the spectral region 650 cm-1 to 1000 cm-1; and within only the spectral region 1000 cm-1 to 2400 cm-1. These show the relative importance of utilizing either 15 micron temperature sounding channels, the 4.2 micron sounding channels, or both, with regards to sounding accuracy. Retrievals using channels in either spectral region alone give comparable performance, which is slightly poorer than that obtained when both are used simultaneously. These results are particularly significant with regard to potential designs for the advanced high spectral IR sounder, HES, being developed for use on the GOES-R Geostationary satellite.

6233-48, Session 9

The use of error estimates with AIRS profiles to improve short-term weather forecasts

G. J. Jedlovec, S. Chou, NASA Marshall Space Flight Ctr.; B. Zavodsky, The Univ. of Alabama in Huntsville; B. Lapenta, NASA Marshall Space Flight Ctr.

The hyperspectral resolution measurements from the NASA Atmospheric Infrared Sounder (AIRS) are advancing climate research by mapping atmospheric temperature, moisture, and trace gases on global basis with unprecedented accuracy. Using a sophisticated retrieval scheme, the AIRS is capable of diagnosing the atmospheric temperature in the troposphere with accuracies of less than 1 K over 1 km-thick layers and 10-20% relative humidity over 2 km-thick layers, under both clear and cloudy conditions. A unique aspect of the retrieval procedure is the specification of a vertically varying error estimate for the temperature and moisture profile for each retrieval. The error specification allows for the more selective use of the profiles in subsequent processing. In this paper we describe a procedure to assimilate AIRS data into the Weather Research and Forecast (WRF) model to improve short-term weather forecasts. The ARPS Data Analysis System (ADAS) developed by the University of Oklahoma was configured to optimally blend AIRS data with model background fields based on the AIRS error profiles. The WRF short-term forecasts with AIRS data show improvement over the control forecast. The use of the AIRS error profiles maximizes the impact of high quality AIRS data from portions of the profile in the assimilation/forecast process without degradation from lower quality data in other portions of the profile.

6233-49, Session 9

Satellite hyperspectral IR sensors for monitoring greenhouse effects

H. K. Burke, J. W. Snow, F. W. Chen, K. E. Farrar, MIT Lincoln

Lab.

The new era of satellite IR hyperspectral sensors designed for weather and other environmental applications provides the potential for change monitoring of carbon dioxide, water vapor and trace gases. These combined can begin to quantify the greenhouse effects as well as climate change monitoring. We first illustrate radiative transfer modeling of the greenhouse effect with examples of varying upper and lower tropospheric water vapor, in addition to surface temperature and tropospheric temperature. We use global AIRS data from several "focus days" to illustrate this application. Specifically, we concentrate on the 1365 to 1615 cm-1 region (~6 to 7 um) to investigate the relative change of lower vs. upper tropospheric water vapor effects.

6233-50, Session 9

Satellite sounder-based OLR-, cloud-, and atmospheric temperature climatologies for climate analyses

G. I. Molnar, J. Susskind, NASA Goddard Space Flight Ctr.

Global energy balance of the Earth-atmosphere system may change due to natural and man-made climate variations. For example, changes in the outgoing longwave radiation (OLR) can be regarded as a crucial indicator of climate variations. Clouds play an important role -still insufficiently assessed-, in the global energy balance on all spatial and temporal scales, and satellites can provide an ideal platform to measure cloud and large-scale atmospheric variables simultaneously. The TOVS series of satellites were the first to provide this type of information since 1979 on. OLR [Mehta and Susskind, 1999], cloud cover and cloud top pressure [Susskind et al., 1997] are among the key climatic parameters computed by the TOVS Path A algorithm using mainly the retrieved temperature and moisture profiles. AIRS can be regarded as the "new and improved TOVS", having much higher spectral resolution and greater S/N ratio, so these climatic parameters can be retrieved with higher accuracy.

First we present encouraging agreements between MODIS and AIRS cloud top pressures (Pc) and 'effective' (Aeff, a product of infrared emissivity at 11 microns and physical cloud cover or Ac) cloud fraction interannual variabilities for selected months. Next we present validation efforts and preliminary trend analyses of TOVS-retrieved Pc and Aeff. For example, the TOVS and ISCCP-AVHRR [available since 1983] cloud fractions correlate strongly, including regional trends. Decadal global trends in Pc and Aeff/Ac are also similar.

We also present TOVS and AIRS OLR validation effort results and (for the longer-term TOVS) trend analyses. OLR interannual spatial variabilities from the available state-of-the-art CERES measurements and both from the AIRS [Susskind et al., 2003] and TOVS OLR computations are in remarkably good agreement. Global mean Monthly CERES and TOVS OLR time series show very good agreement in absolute values also. Finally, we will assess potential correlations among interannual variabilities of these parameters and that of mean tropospheric temperature, also derived from simultaneous AIRS/TOVS soundings.

6233-51, Session 9

Neural network retrieval of atmospheric temperature and moisture profiles from AIRS/AMSU data in the presence of clouds

W. J. Blackwell, MIT Lincoln Lab.

A novel statistical method for the retrieval of atmospheric temperature and moisture (relative humidity) profiles has been developed and evaluated with sounding data from the Atmospheric InfraRed Sounder (AIRS) and the Advanced Microwave Sounding Unit (AMSU). The present work focuses on the cloud impact on the AIRS radiances and explores the use of stochastic cloud clearing mechanisms together with neural network estimation. A stand-alone statistical algorithm will be presented that operates directly on cloud-impacted AIRS/AMSU data, with no need for a physical cloud clearing process.

The algorithm is implemented in three stages. First, the infrared radiance perturbations due to clouds are estimated and corrected by combined processing of the infrared and microwave data using a Stochastic Cloud Clearing (SCC) approach. The cloud clearing of the infrared radiances was performed using principal components analysis of infrared brightness temperature contrasts in adjacent fields of view and microwave-derived estimates of the infrared clear-column radiances to estimate and correct the radiance contamination introduced by clouds. Second, a Projected Principal Components (PPC) transform is used to reduce the dimensionality of and optimally extract geophysical profile information from the cloud-cleared infrared radiance data. Third, an artificial feedforward neural network (NN) is used to estimate the desired geophysical parameters from the projected principal components.

The performance of this method (henceforth referred to as the SPN method) was evaluated using global (ascending and descending) EOS-Aqua orbits co-located with ECMWF fields for a variety of days throughout 2003 and 2004. Over 350,000 fields of regard (3x3 arrays of footprints) over ocean and land were used in the study. Retrieval performance compares favorably with that obtained with simulated observations from the NOAA88b radiosonde set of approximately 7500 profiles. The SPN method requires significantly less computation than traditional variational retrieval methods, while achieving comparable performance.

6233-52, Session 10

MODTRAN5: 2006 update

G. P. Anderson, Air Force Research Lab.; A. Berk, P. K. Acharya, L. S. Bernstein, L. Muratov, J. Lee, M. J. Fox, S. M. Adler-Golden, Spectral Sciences, Inc.; J. H. Chetwynd, Jr., M. L. Hoke, R. B. Lockwood, J. A. Gardner, T. W. Cooley, Air Force Research Lab.; C. C. Borel, Ball Aerospace & Technologies Corp.; P. E. Lewis, National Geospatial-Intelligence Agency

The MODTRAN5 radiation transport (RT) model is a major advancement over earlier versions of the MODTRANÔ atmospheric transmittance and radiance model. New model features include (1) finer spectral resolution via the Spectrally Enhanced Resolution MODTRAN (SERTRAN) molecular band model, (2) a fully coupled treatment of auxiliary molecular species, and (3) a rapid, high fidelity multiple scattering (MS) option. The finer spectral resolution improves model accuracy especially in the mid- and long-wave infrared atmospheric windows; the auxiliary species option permits the addition of any or all of the suite of HITRAN molecular line species, along with default and user-defined profile specification; and the MS option makes feasible the calculation of Vis-NIR databases that include high-fidelity scattered radiances. Validations of the new band model algorithms against LBL codes have proven successful.

6233-53, Session 10

Applying the OSS radiative transfer method to MODTRAN

H. E. Snell, T. C. Connor, T. S. Zaccheo, AER Inc.; A. Berk, Spectral Sciences, Inc.

The Optimal Spectral Sampling (OSS) method models band averaged radiances as weighted sums of monochromatic radiances. The method is fast and accurate and has the advantage over other existing techniques that it is directly applicable to scattering atmospheres. Other advantages conferred by the method include flexible handling of trace species and ability to select variable species at run time without having to retrain the model, and the possibility of large speed gains by specializing the model for a particular application. The OSS method is used in the CrIS and CMIS retrieval algorithms and it is currently being implemented in the Joint Center for Satellite Assimilation (JCSDA) Community Radiative Transfer Model (CRTM). A version of OSS is currently under development for direct inclusion within MODTRAN, as an alternative to the current band models. This paper discusses the MODTRAN/OSS interface, presents model results, and identifies new developments applicable to narrowband and broadband radiative transfer modeling across the spectrum and the training of OSS for scattering atmospheres.

6233-54, Session 10

Reflectance recovery for AVIRIS scenes

K. Chandra, G. E. Healey, Univ. of California/Irvine

We analyze a nonlinear algorithm for reflectance recovery in the airborne visible/infrared imaging spectrometer (AVIRIS) scenes. The algorithm is based on the use of a finite-dimensional linear model for the reflectance spectra. We use a coupled subspace model for the solar radiance, sky radiance, and path-scattered radiance to model their common dependence on the environmental condition and viewing geometry. The method also models varying orientations of the material surfaces. The Levenberg-Marquardt method is used in our algorithm for estimating the subspace model parameters. The estimated reflectance subspace model parameters determine the recovered reflectance spectrum. We apply the algorithm to spectrally pure pixels in the AVIRIS scene of Cuprite, Nevada and analyze the accuracy of the recovered reflectance spectra.

6233-55, Session 11

Analysis of a multi-temporal hyperspectral dataset over a common target scene

D. W. Messinger, M. Richardson, Rochester Institute of Technology

As hyperspectral sensors become more available for commercial use, an understanding of the impact of “natural change” on exploitation of that imagery is required. During the summer of 2005, the RIT Digital Imaging and Remote Sensing Laboratory, in conjunction with the Laboratory for Imaging Algorithms and Systems, undertook a collection campaign of a common target scene with a Vis / NIR hyperspectral sensor. The Modular Imaging Spectrometer Instrument (MISI) has 70 channels from 0.4 um to 1.0 um and was flown over the RIT campus on six different dates between May and September along a common flightline. Flights were spaced by as little as 3 days and as long as a month. Twice, multiple flightlines were collected on a single day, separated by minutes and hours. Calibration panels were placed in the scene and characterized for correction of the images. Several experiments were run during individual flights, but the goal here is to describe and understand the temporal aspects of the data. Results from classifying each image will be presented to show how local weather history, slightly different collection geometries, and real scene change affect the results. Similarly, common regions of interest in the imagery will be defined and comparisons will be made of the statistical variations in the regions across the season. These changes will be linked to weather history and anthropomorphic activities.

6233-56, Session 11

Design and modeling of spectral-thermal unmixing targets for airborne hyperspectral imagery

P. E. Clare, Defence Science and Technology Lab. (United Kingdom)

Techniques to determine the proportions of constituent materials within a single pixel spectrum are well documented in the reflective (0.4-2.5micron) domain. The same capability is also desirable for the thermal (7-14micron) domain, but is complicated by the thermal contributions to the measured spectral radiance. Atmospheric compensation schemes for the thermal domain have been described along with methods for estimating the spectral emissivity from a spectral radiance measurement and hence the next stage to be tackled is the unmixing of thermal spectral signatures. In order to pursue this goal it is necessary to collect data of well-calibrated targets which will expose the limits of the available techniques and enable more robust methods to be designed. This paper describes the design of a set of ground targets for an airborne hyperspectral imager, which will test the effectiveness of available methods. The set of targets include panels to explore a number of difficult scenarios such as isothermal (different materials at identical temperature), isochromal (identical materials, but at differing temperatures), thermal adjacency and thermal point sources. Practical fabrication issues for heated targets and selection of appropriate materials are described. Mathematical modelling of the experiments has enabled prediction of at-sensor measured radiances which are used to prove the design parameters. Finally, a number of useful lessons learned during the fielding of these actual targets are presented to assist those planning future trials of thermal hyperspectral sensors.

6233-57, Session 11

Tree canopy closure assessment using digital photography

P. C. Baker, Science Applications International Corp.; C. S. Allen, Northrop Grumann Corp.

Tree canopy closure is often a desired metric in ecological applications of spectral remote sensing. There are numerous models and field protocols for estimating this variable, many of which are specialized or which have poor accuracies. Specialized instruments are also available but they may be cost prohibitive for small programs. An expedient alternative is the use of in-situ handheld digital photography to estimate canopy closure. This approach is cost effective while maintaining accuracy. The objective of this study was to develop and test an efficient field protocol for determining tree canopy closure from zenith-looking and oblique digital photographs.

Investigators created a custom software package that uses Euclidean distance to cluster pixels into sky and non-sky categories. The percentages of sky and tree canopy are calculated from the clusters. Acquisition protocols were tested using JPEG photographs taken at multiple upward viewing angles and along transects within an open stand of loblolly pine trees and a grove of broadleaf-deciduous trees. JPEG lossy compression introduced minimal error but provided an appropriate trade-off given limited camera storage capacity and the large number of photographs required to meet the field protocol. This is in contrast to relatively larger error introduced by other commonly employed measurement techniques such as using gridded template methods and canopy approximations calculated by tree diameter measurements.

Experiment results demonstrated the viability of combining image classification software with ground-level digital photographs to produce fast and economical tree canopy closure approximations.

6233-58, Session 11

Reflectance of water-wetted sand

M. B. Satterwhite, Science Applications International Corp.

Water wets soil via two processes. First, water adsorbs to soil granular materials, creating a film around particles. Second, water fills interstitial pore spaces via percolation and capillary flow. Water accumulates on the surface when soil percolation rates are low. When applied to soil, water’s differential absorption in the reflective portion of the electromagnetic spectrum creates non-uniform changes in sample spectra. This study’s objective was to measure changes in soil reflectance spectra relative to soil water differences.

The water was incrementally applied to six sand substrata that varied by particle size distribution and chemical composition. Each sample was water wetted by spray application. Initial water applications greatly reduced soil reflectance and masked spectral features of the air-dry soil. Reflectance differences in the VIS/NIR/SWIR regions were related to water transmittance and absorption differences. Water-Spectralon(tm) samples with 0.008-15.7 mm films also demonstrated these differences. Water films \>3.5 mm in depth on Spectralon(tm) quenched the short wave infrared (SWIR) reflectance and attenuated visible-near infrared (VIS-NIR) reflectance.

Reflectance maxima occurred in five spectral bands, centered at 0.800, 1.065, 1.265, 1.695, and 2.220 μm. These maxima varied inversely with sample water content. The rate of spectral change and band sensitivities

increased with wavelength. The 0.800 and 1.065 μm bands varied more slowly with water content than did the 1.265, 1.695, and 2.220 μm bands. Multiple normalized difference indices (NDI) using these bands correlated strongly with soil water content. The NDI's describe qualitative soil-moisture conditions such as air-dry, damp, moist, saturated, and a standing surface film of water. The soils also have anisotrophic reflectance differences in the VIS-NIR and SWIR regions that were related to water transmittance and absorption differences.

6233-59, Session 11

Reflectance spectra of some liquid hydrocarbons on a sand

C. S. Allen, Northrop Grumman Corp.; M. B. Satterwhite, Science Applications International Corp.

Liquid hydrocarbons of widely varying volatilities were incrementally applied to a quartz sand substrate. These liquids were gasoline, diesel fuel, and motor oil. The reflectance of the hydrocarbon-sand samples varied directly with the amount (weight) of liquid on the sand. Liquid-saturated sand samples were then left to age in ambient, outdoor, environmental conditions. At regular intervals, the samples were re-measured for the residual liquid and the associated change in sample reflectance. The results outlined temporal windows of opportunity for detecting these products on the sand substrate. The windows ranged from less than 24-hours to more than a week, depending on liquid volatility.

All hydrocarbons darkened the sand and produced a spectrum with lower reflectance. They also produced hydrocarbon absorption features near 1.70 and 2.31μm and a hydrocarbon plateau, all of which differentiated the liquid-sand samples. A normalized difference index metric based on one of these features and an adjacent continuum band described weight loss-reflectance and reflectance-time relationships. A normalized difference hydrocarbon index (NDHI) using the 1.60 and 2.31μm bands, characterized the samples and differentiated the hydrocarbons from one another.

6233-60, Session 11

MWIR plume radiance phenomenology

C. R. Quick, Jr., R. R. Petrin, Los Alamos National Lab.

There are several industrial pollutants that have unique or strong absorption/emission signatures in the mid-wave infrared (MWIR) region of the spectrum. Until recently the use of the MWIR region has been hampered by a lack of detailed understanding of the phenomenology influencing the at-sensor radiance. The goal of this paper is to increase understanding of this phenomenology and thus the utility of the MWIR spectral region for industrial pollution monitoring applications.

There are significant differences between the MWIR (3-5 microns) and LWIR (7-14 microns) regions of the spectrum when it comes to passive multi/hyperspectral sensor detection of chemical plumes in the open atmosphere. At issue are the relative sizes of the radiance terms that contribute to the at-sensor radiance, and how the various terms interact with a chemical plume that may be present within the scene being imaged. Several of the radiance terms that are often neglected in the LWIR region can become the dominant terms in the MWIR and thus cannot, in general, be neglected without a deleterious effect on ones ability to detect and identify chemical plumes. The most obvious example is the reflected solar scatter term, which can easily become the largest radiance term in the 3-4 micron region under conditions of strong illumination and highly reflective surface material.

The goal in the material that follows is to approximately quantify the range of potential variability in the radiance terms in the MWIR and illustrate, by example, some of the consequences on chemical plume detection sensors. Radiance terms will be estimated using the MODTRAN4 radiance transport code. The issues discussed here include: relative magnitude of radiance terms, sensor dynamic range requirements, radiance contrast effects, plume shadow effects, and multi-path distortion of plume spectral signatures.

6233-61, Session 11

The relationship between air pollution and satellite data from OCTS

C. J. Wong, Univ. Sains Malaysia (Malaysia)

Air quality is a major concern in many large cities of the world. This paper studies the relationship between particulate matter of size less than 10-micron meter (PM10) and satellite observation from OCTS. The objective of this study is to map the PM10 distribution in Peninsular Malaysia using visible and thermal bands data. The in-situ PM10 measurements were collected simultaneously with the acquisition of the satellite image. The reflectance values in the visible and digital numbers in the thermal bands were extracted corresponding to the ground-truth locations and later used for algorithm regression analysis of the air quality. A developed algorithm was used to predict the PM10 values from the satellite image. The novelty of this study is the algorithm uses a combination of reflectance measurements from the visible bands and the corresponding apparent temperature values of the thermal band. This study investigates the relationship between the extracted OCTS signals and the PM10 values. The reflectance at 3.55-3.88 micro meter is computed after correction for the emission by the atmosphere. The surface emissivity values were computed based on the NDVI values. The developed algorithm produced a high correlation between the measured and estimated PM10 values of 0.97. Finally, a PM10 map was generated over Peninsular Malaysia using the proposed algorithm. This study has indicated the potential of OCTS satellite data for air quality study.

6233-62, Session 12

Analysis LIDAR and spectral imagery for scene classification in forested areas

M. F. Helt, R. C. Olsen, A. M. Puetz, Naval Postgraduate School

LIDAR data and multispectral imagery from the Quickbird satellite were combined to study terrain classification in a forested area. LIDAR data were taken over the Elkhorn Slough in Central California on April 12th, 2005. The Optech ALTM 2025 sensor was flown by Airborne 1. The primary element of interest was to determine if tree type could be distinguished in the 10 Å~ 20 km region which is mixed use agriculture and wetlands.

Time return and intensity were obtained at ~2.5 postings. Quickbird imagery was from October 2002. Ground truth was combined with the orthorectified satellite imagery to determine regions of interest for areas with Eucalyptus, Scrub Oak, Live Oak, and Monterey Cyprus trees. LIDAR temporal returns could be used to distinguish regions with trees from cultivated and bare soil areas. Some tree types could be distinguished on the basis of relationship between first/last extracted feature returns. The otherwise similar Eucalyptus and Monterey Cyprus could be distinguished by means of the intensity information from the imaging LIDAR. The combined intensity and temporal data allowed accurate distinction between the tree types, and task not otherwise practical with the satellite spectral imagery.

6233-63, Session 12

Anomaly detection using the hyperspectral imaging testbed system

D. B. Cavanaugh, Surface Optics Corp.

The Hyperspectral Polarimetric Imaging Testbed (HPIT) contains a VNIR, SWIR, and three-axis imaging polarimeter, each operating simultaneously through a common fore-optic. The system was designed for the detection of man-made objects in natural scenes. The imagery produced by the various imaging legs of the HPIT system is readily fused, due to the identical image format, FOV and IFOV of each optical leg. The fused imagery is proven useful for the detection of a variety of man-made surfaces. This paper describes the general design and function of the mature HPIT system, the Stochastic Gaussian Classifier processing method

used for hyperspectral anomaly detection, the polarimetric image processing methods, and a logical decision structure for the identification of various surface types. The paper will also describe in detail the detection results for a variety of targets obtained in field testing conducted with the HPIT system.

6233-64, Session 12

High-performance fusion of multispectral and hyperspectral data

M. E. Winter, Univ. of Hawai'i at Manoa; E. M. Winter, Technical Research Associates, Inc.; S. G. Beaven, Space Computer Corp.; A. J. Ratkowski, Air Force Research Lab.

Multispectral sharpening of hyperspectral imagery fuses the spectral content of a hyperspectral image with the spatial and spectral content of the multispectral image. The approach we have been investigating compares the spectral information present in the multispectral image to the spectral content in the hyperspectral image and derives a set of equations to approximately transform the multispectral image into a synthetic hyperspectral image. This synthetic hyperspectral image is then recombined with the original low-resolution hyperspectral image to produce a sharpened product. We evaluate this technique against several types of data, showing good performance across with all data sets. Recent improvements in the algorithm allow target detection to be performed without loss of performance even at extreme sharpening ratios.

6233-65, Session 12

Overcoming combined effect of geometric distortion and object change in image registration and conflation

B. Kovalerchuk, Y. Kamatkova, Central Washington Univ.

A persistent problem with new unregistered geospatial data is geometric image distortion caused by different sensor location and other factors. Often this distortion is modeled by means of arbitrary affine transformations. However in most of the real cases such geometric distortion is combined with other distortions that makes the problem much more difficult. Often images overlap only partially with objects on images that have some common parts. This is cut-distortion of image objects. Moreover the same objects on two images can differ because of many factors such as different resolution, atmospheric effects, and others. This provides resolution distortion of image objects, and atmospheric distortion of image objects. The geometric distortion preserves one-to-one match between all points of the same object in the two images. In contrast with that, cut distortion and resolution distortion do not preserve one-to-one point match. Some points may have no match at all in the matched object. We call such distortions object change distortion.

Different invariants for affine transforms are known and used in building some affine invariant registration algorithms. However most of the algorithms are very sensitive to object change. This paper is focused on developing a robust method to provide computational tools to automate a large portion of the process without relying on the sensor geometry and model that may be unknown. Effective point placement, feature interpolation, and super-feature construction methods are developed to overcome the combined effect of geometric distortion and object change.

6233-66, Session 13

Nonlinear signal contamination effects for gaseous plume detection in hyperspectral imagery

J. Theiler, B. R. Foy, A. M. Fraser, Los Alamos National Lab.

When a matched filter is used for detecting a weak target in a cluttered background (such as a gaseous plume in a hyperspectral image), it is important that the background clutter be well-characterized. A statistical characterization can be obtained from the off-plume pixels of a hyperspectral image, but if on-plume pixels are inadvertently included, then that background characterization will be contaminated. In broad area search scenarios, where detection is the central aim, it is not necessarily known which pixels in a scene are off-plume. The contaminated background degrades the ability of the matched-filter to detect that signal, but it is not obvious that this is a practical problem — if the plume is weak, it will not produce much contamination; and if it is strong, it will be easy to detect anyway. A linear analysis [Theiler and Foy, GRSL (2005), to appear] suggests that the effect is not that large in general, and actually vanishes in some cases. In this study, the Beers Law nonlinearity of plume absorption will be taken into account, and the effect of that nonlinearity on the signal contamination effects will be investigated.

6233-67, Session 13

Land surface temperature and emissivity retrieval from thermal infrared hyperspectral imagery

M. Boonmee, J. R. Schott, D. W. Messinger, Rochester Institute of Technology

A new algorithm was developed to retrieve land surface temperature (LST) and emissivity from airborne thermal infrared hyperspectral data. The algorithm consists of a preprocessing stage, an iterative near-blackbody pixels search, and an iterative constrained optimization loop. The preprocessing stage provides initial estimates for LST per pixel and the atmospheric parameters of transmittance and upwelling radiance for the entire image. This stage is based on the well established in-scene atmospheric compensation (ISAC) algorithm. The estimates of LST are determined from the maximum brightness temperature per pixel. Estimates for atmospheric transmittance and upwelling radiance are determined by fitting a linear equation to the observed radiance versus blackbody radiance scatterplot for each band. A search for near-blackbody pixels determines which pixels were under- or over-fitted by the linear regression and classifies them as near-blackbody and lower emissivity pixels, respectively. The atmospheric parameters are ecalculated using the near-blackbody pixels and the process is repeated until a stopping criterion is reached. The downwelling radiance is estimated from the upwelling radiance by applying a look up table of coefficients based on a polynomial regression of MODTRAN runs for the same sensor altitude. A constrained optimization of the atmospheric parameters using generalized reduced gradients on the near-blackbody pixels ensures physical results. The LST and emissivity per pixel are retrieved using the well established iterative spectrally smooth temperature-emissivity separation (ISSTES) algorithm. The new algorithm can retrieve LST within about ± 2.0 K, and emissivities within about ± .02 based on numerical simulation.

6233-68, Session 13

Temperature/emissivity separation (TES) utilizing a temperature-modulated spectrally-homogeneous region: an alternative perspective

K. M. Lausten, R. G. Resmini, The Boeing Co. and The National Geospatial-Intelligence Agency

The extraction of emissivity signatures from thermal infrared (TIR) hyperspectral imagery (HSI) is an under-determined problem due to the temperature dependence of ground-leaving radiance (GLR). The development of emissivity spectra is key to the exploitation of TIR HSI because the emissivity spectrum is a fundamental material identification datum. Numerous approaches have been developed to perform temperature emissivity separation (TES) with varying levels of success. Here, a method is presented that exploits a spectrally homogeneous region with multiple temperatures due to spatially variant degrees of thermal shadows (virtual cold) resulting from either natural terrain relief and/or manmade structures. The method is related to those of Watson (1992a,b) though distinct in its use of modeling. The current approach is based on the construction of successive two-band GLR scatter plots derived from actual

TIR HSI data of a temperature modulated, spectrally (compositionally) homogeneous area. These scatter plots are generally linear if a spectrally homogeneous region has been successfully identified. Model GLR scatter plots are then generated with the Planck function to match those derived from the data. Model temperatures are selected to match the spread in the actual TIR HSI data. However, emissivity is an unknown in the modeling step. Thus, numerous two-band modeled-GLR scatter plots are generated for a wide range of emissivity values. The slopes of the modeled GLR plots are used to generate a nomogram (ratio of emissivities used to generate GLR values vs. slope of GLR plot). The slopes of the actual data-derived GLR plots are matched to the nomogram to generate an emissivity ratio value. An emissivity ratio spectrum is created; existing techniques may be used to select an emissivity value for one band thus facilitating the conversion of the ratio spectrum to a conventional emissivity spectrum. Or, an emissivity spectral library may be converted to ratio spectra and used in exploitation. The presentation will describe the TES technique and present emissivity results derived from airborne TIR HSI.

6233-69, Session 13

Airborne mapping of chemical plumes in the aftermath of Hurricanes Katrina and Rita

P. E. Lewis, National Geospatial-Intelligence Agency; B. Kroutil, Los Alamos National Lab.; M. J. Thomas, U.S. Environmental Protection Agency Region VII; R. J. Combs, Research and Technology Consultants; T. Curry, U.S. Environmental Protection Agency Region VII; A. Cummings, Tetra Tech EM Inc.

Infrared airborne spectral measurements were collected in the Gulf Coast area during the aftermath of Hurricanes Katrina and Rita to survey for potentially hazardous chemical vapor releases from industrial facilities. Data was collected using a mid-longwave infrared multispectral imager and a hyperspectral Fourier Transform Infrared (FT-IR) spectrometer operating in a low altitude aircraft. The data was processed to evaluate chemical spectral signatures in the presence of interferents, atmospheric contributions, and thermal clutter. Results were obtained confirming the presence of a number of chemical vapors. All information was immediately passed along to emergency first responders on the ground. The chemical identification, location, and species concentration information was used by the emergency response ground teams for identification of critical plume releases for immediate mitigation. This presentation will discuss the methodology used and results obtained during the Katrina and Rita emergency response flights.

6233-70, Session 13

Hyperspectral requirements for detection of trace explosive agents

H. C. Schau, Raytheon Co.

The ability to detect minute traces of explosive compounds has become an active application area of applied spectroscopy. Moderate spectral resolution and the ability to perform a rapid wide-area search make hyperspectral imaging a natural choice for passive trace explosives detection. We present experimental results describing the spectral features and resolution required to make a feasible trace explosives detection system. Methodology for hyperspectral trace explosives detection is discussed and algorithms for hyperspectral detection are presented. Difficulties with simple spectral detection are reviewed and combined spectral/spatial methods are discussed. Detection results are shown for a laboratory feasibility test.

6233-71, Session 14

Fast Monte Carlo full-spectrum scene simulation

S. Richtsmeier, R. L. Sundberg, Spectral Sciences, Inc.; F. O. Clark, R. E. Haren, Air Force Research Lab.

This paper will discuss the formulation and implementation of an acceleration approach for the MCScene code, which is a high fidelity model for full optical spectrum (UV to LWIR) hyperspectral image (HSI) simulation. The MCScene simulation is based on a Direct Simulation Monte Carlo approach for modeling 3D atmospheric radiative transport, as well as spatially inhomogeneous surfaces including surface BRDF effects. The model includes treatment of land and ocean surfaces, 3D terrain, 3D surface objects, and effects of finite clouds with surface shadowing. This paper will review an acceleration algorithm that exploits spectral redundancies in hyperspectral images. In this algorithm, the full scene is determined for a subset of spectral channels, and then this multispectral scene is unmixed into spectral endmembers and endmember abundance maps. Next pure endmember pixels are determined at their full hyperspectral resolution and the full hyperspectral scene is reconstructed from the hyperspectral endmember spectra and the multispectral abundance maps. This algorithm effectively performs a hyperspectral simulation while requiring only the computational time of a multispectral simulation. The acceleration algorithm will be demonstrated on several scenes containing representative terrain types and a variety of materials. Errors associated with the algorithm will be analyzed and the trade between the acceleration factor, number of channels for multispectral calculation, and the resulting errors will be investigated.

6233-72, Session 14

Application of large-eddy simulations of industrial effluents for hyperspectral remote sensing systems

D. S. DeCroix, Los Alamos National Lab.

Plume and industrial effluent modeling is an area our team has been actively involved in for a number of years. Most recently we have developed modeling tools that are being used for hyperspectral sensor analysis.

The plume modeling codes predict the concentration and temperature of a release as a function of space and time as the effluent flows in and around buildings and obstacles. Two main codes are being actively developed, one a fast running urban dispersion model that couples a mass consistent wind model with a Lagrangian dispersion code that computes mean wind and effluent concentrations. The other is a large-eddy simulation code that provides high spatial and temporal resolution of instantaneous concentrations and temperatures, including turbulent fluctuations, simulating realistic variability in the effluent dispersion. Once the plumes have been modeled for a specific site, an invariant chemical composition is assumed at the effluent source location, and the plume model concentrations are scaled appropriately for a given flow rate. A composite spectrum is defined using existing libraries of individual gas spectra for the portion of the spectrum. From the resultant plume simulations, we have the concentration and temperature of the effluent gas has a function of three-dimensional space and time. We then compute the plume radiance and transmittance for the assumed gas mixture, and superimpose this “flattened” plume over the site. We then compute the effect of the surface materials and their radiance and transmittance through the plume and atmosphere to a hyperspectral (or multispectral) instrument.

In the presentation we will show several simulations of plumes, will show how these plumes would look as seen by a hyperspectral instrument and will discuss the effects of steady state and temporally evolving plume concentration and radiance on the sensors minimum detectable quantity.

6233-73, Session 14

Hyperspectral clutter statistics, generative models, and anomaly detection

O. J. Watkins, M. Bernhardt, J. P. Heather, Waterfall Solutions Ltd. (United Kingdom)

Detection of Anomalies in hyperspectral clutter is becoming an increasingly important task in military surveillance. Most algorithms for unsupervised anomaly detection make either explicit or implicit assumptions about hyperspectral clutter statistics; for instance that the abundance are either

normally distributed or elliptically contoured. In this paper we investigate the validity of such claims. We show that while non-elliptical contouring is not necessarily a barrier to anomaly detection, it may be possible to do better. To achieve this performance improvement we propose using generative models which replicate the competitive behaviour of vegetation at a mathematically tractable level, thus providing an alternative means of understanding clutter statistics and hence performing anomaly detection.

6233-74, Session 14

Johnson distribution models of hyperspectral image data clusters

E. C. Meidunas, S. C. Gustafson, Air Force Institute of Technology; D. G. Manolakis, MIT Lincoln Lab.

The Johnson System for characterizing an empirical distribution is used to model the non-normal behavior of Mahalanobis distances in material clusters extracted from hyperspectral imagery data. An automated method for determining Johnson distribution parameters is used to model Mahalanobis distance distributions and is compared to another method which uses mixtures of F distributions. The results lead to a method for determining outliers and mitigating their effects. Also, it is suggested that the Johnson system parameters may be used in providing insight to tie stochastic hyperspectral exploitation methods to subspace methods for hyperspectral data analysis.

6233-75, Session 14

Principle of indirect comparison (PIC): simulation and analysis of PIC-based anomaly detection in multispectral data

D. S. Rosario, Army Research Lab.

The Army Research Lab (ARL) has gained a renewed interest in hyperspectral (HS) imagery for military surveillance. As a result, a formal HS research team has been established at ARL to focus exclusively on the design of innovative anomaly detection algorithms for target detection in natural clutter. In 2005 at this conference, we presented comparison performances between an ARL algorithm and existing ones testing real HS data. For 2006, we will present insightful information on our general approach using analyses of statistical performances of additional ARL algorithms testing 1500 simulated realizations of model-specific data to shed some light on their effectiveness. Simulated data of increasing background complexity will be used for the analysis, where highly correlated multivariate Gaussian random samples will model homogeneous backgrounds and mixtures of Gaussian will model non-homogeneous backgrounds. Distinct multivariate random samples will model targets, and targets will be added to backgrounds. The principle that led to the design of our detectors employs an indirect sample comparison to test the likelihood that local HS random samples belong to the same population. Let X and Y denote two random samples, and let Z = X U Y, where U denotes the union. We showed that X can be indirectly compared to Y by comparing, instead, Z to Y (or to X). Mathematical implementations of this simple idea have shown a remarkable ability to preserve performance of meaningful detections (e.g., full-pixel targets), while significantly reducing the number of meaningless detections (e.g., transitions of background regions in the scene).

6233-76, Session 15

Academic research program at the National Geospatial-Intelligence Agency

S. A. Loomer, National Geospatial-Intelligence Agency

Abstract not available

6233-77, Session 16

Improving the hyperspectral linear unmixing problem with unsupervised clustering and covariance estimates

E. Brevdo, Princeton Univ.; K. Luu, Air Force Research Lab.

The hyperspectral subpixel detection and classification problem has been intensely studied in the downward-looking case, e.g., satellite imagery of agricultural and urban areas. The hyperspectral imaging case when “looking up” at small or distant satellites creates new and unforeseen problems. Usually one pixel or one fraction of a pixel contains the imaging target, and spectra tend to be time-series data of a single object collected over some time period under possibly varying weather conditions; there is little spatial information available. Often, the number of collected traces is less than the number of wavelength bins, and a materials database with imperfect representative spectra must be used in the subpixel classification and unmixing process. We formulate a procedure for generating a “good” set of classes from experimentally collected spectra by assuming a Gaussian distribution in the angle-space of the spectra. Specifically, we use Kernel K-means, a suboptimal ML-estimator, to generate a set of classes. We then use covariance information from the resulting classes and weighted least squares methods to solve the linear unmixing problem. We show with cross-validation that Kernel K-means separation of laboratory material classes into “smaller” virtual classes before unmixing improves the performance of weighted least squares methods.

6233-78, Session 16

A comparison of algorithms to compute the positive matrix factorization and their application to unsupervised unmixing

Y. M. Masalmah, M. Vélez-Reyes, Univ. de Puerto Rico Mayagüez

In hyperspectral imagery (HSI), hundreds of images are taken at narrow and contiguous spectral bands providing us with high spectral resolution spectral signatures that can be used to discriminate between objects. In many applications, the measured spectral signature is a mixture of the target of interest, clutter and other objects within the field of view of the sensor. In order to determine which object is in the field of view of the sensor, we can use the high spectral resolution information to decompose the measured spectral signature in its constituents and their contribution to the measured spectra. This is the so called unmixing problem. This paper presents a comparison of different algorithms to compute the positive matrix factorization and their application to the unsupervised unmixing problem. We study the performance of numerical methods based on the Gauss-Newton algorithm, Seung-Lee approach, and penalty methods. Preliminary results using simulated and HYPERION imagery will be presented. Algorithms will be compared in terms of their computational complexity and quality of the results.

6233-79, Session 16

Error rates of unmixed hyperspectral imagery

M. E. Winter, Univ. of Hawai’i at Manoa

Unmixing using as set of scene derived spectra represents a powerful and widely used method of exploiting hyperspectral data. There are a variety of algorithms designed to find end-members, including ORASIS, N-FINDR, IEA, and PPI. Additionally, there are a variety of methods to unmix an image, including simple and constrained least squares, and total least squares. Using hundreds of synthetic images, this paper examines all of these methods for an estimate as to how accurate they are. Error rates in terms of how close a end-member is to actual in scene end-members will be shown, as well as error rates of fraction plane imagery. This information may prove useful in guiding the exploitation of using end-member analysis.

6233-80, Session 16

Evaluations of spectral unmixing algorithms using ground based satellite imaging

J. F. Scholl, College of Optical Sciences/The Univ. of Arizona; E. K. Hege, MKS Imaging Technology, LLC and Steward Observatory/The Univ. of Arizona; D. O'Connell, Oceanit, Inc.; W. R. Johnson, Jet Propulsion Lab.; E. L. Dereniak, College of Optical Sciences/Univ. of Arizona

Abundances of material components in objects are usually computed using techniques such as linear spectral unmixing on individual pixels captured on hyperspectral imaging devices. However, algorithms such as unmixing have many flaws, some due to the implementation, and others due to improper choices of the spectral library used in the unmixing. There also may exist other methods for extraction of this hyperspectral abundance information. We propose the development of spatial ground truth data from which various unmixing algorithm analyses can be evaluated. This may be done by implementing a three-dimensional hyperspectral discrete wavelet transform (HSDWT) with a low-complexity lifting implementation of the Haar basis. The unmixing or similar algorithms can then be evaluated, and their effectiveness can be measured by how well or poorly the spatial and spectral characteristics of the satellite are reproduced at full resolution.

6233-81, Session 17

Feature selection for spectral sensors with overlapping noisy spectral bands

B. S. Paskaleva, M. M. Hayat, J. S. Tyo, Z. Wang, M. L. Martinez, The Univ. of New Mexico

Quantum-dot infrared photodetectors (QDIPs) are emerging as a promising technology for midwave- and longwave-infrared sensing and spectral imaging. One of the key advantages that QDIPs offer is their bias-dependent spectral response, which is a result of introducing certain asymmetries in the dots' shapes. Outputs (photocurrents) of a single QDIP operated at different operational biases can therefore be viewed as outputs of different bands. It has been shown that this property, combined with post-processing strategies (applied to the outputs of a single sensor operated at different biases), can be used to perform adaptive spectral tuning and matched filtering. However, unlike traditional sensors, bands of a QDIP exhibit significant spectral overlap, which calls for the development of novel methods for feature selection. Additionally, the presence of detector noise further complicates such feature selection. In this paper, the theoretical foundations for discriminant analysis based on spectrally adaptive feature selection are developed and applied to data obtained from QDIP sensors in the presence of noise. The undertaken approach is based on a generalized canonical-correlation-analysis framework in conjunction with two optimization criteria for the selection of feature subspaces. The first criterion ranks the best linear combinations of the overlapping bands, providing minimal energy norm (a generalized Euclidean norm) between the centers of each class and their respective reconstructions in the space spanned by sensor bands. In the second criterion, optimal linear combinations of bands are selected to maximize separability among the classes based on the Bhattacharya distance. Experiments using ASTER-based synthetic QDIP data are used to illustrate the performance of rock-type Bayesian classification according to the proposed feature-selection methods.

6233-82, Session 17

Fukunaga-Koontz transform based dimensionality reduction for hyperspectral imagery

S. Ochilov, M. S. Alam, A. Bal, Univ. of South Alabama

The Fukunaga-Koontz transform (FKT) based technique offers some attractive properties for target oriented dimensionality reduction in hyperspectral imagery. In FKT, feature selection is performed by transforming into a new space where feature classes have complimentary eigenvectors. By selecting a few eigenvectors which are most relevant to target class, one can reduce the dimension of hyperspectral cube. Since the FKT based technique reduces data size, it provides significant advantages for near real time target detection applications in hyperspectral imagery. Furthermore, the eigenvector selection approach significantly reduces computation burden via the dimensionality reduction processes. The performance of the proposed FKT based dimensionality reduction algorithm has been tested using real-world hyperspectral dataset.

6233-83, Session 17

Linearly constrained band selection for hyperspectral imagery

S. Wang, C. Chang, Univ. of Maryland/Baltimore County

Linearly constrained adaptive beamforming has been used to design hyperspectral target detection algorithms such as constrained energy minimization (CEM) and linearly constrained minimum variance (LCMV). It linearly constrains a desired target signature while minimizing interfering effects caused by other unknown signatures. This paper investigates this idea and further uses it to develop a new approach to band selection, referred to as linear constrained band selection (LCBS) for hyperspectral imagery. It interprets a band image as a desired target signature while considering other band images as unknown signatures. With this interpretation, the proposed LCBS linearly constrains a band image while also minimizing band correlation or dependence caused by other band images. As a result, two different methods referred to as Band Correlation Minimization (BCM) and Band Correlation Constraint (BCC) can be developed for band selection. Such LCBS allows one to select desired bands for data analysis. In order to determine the number of bands required to select, p, a recently developed concept, called virtual dimensionality (VD) is used to estimate the p. Once the p is determined, a set of p desired bands can be selected by LCBS. Finally, experiments are conducted to substantiate the proposed LCBS.

6233-84, Session 17

Spectral feature probabilistic coding for hyperspectral signatures

S. Chakravarty, C. Chang, Univ. of Maryland/Baltimore County

Spectral signature coding has been used to characterize spectral features where a binary code book is designed to encode an individual spectral signature and the Hamming distance is then used to perform signature discrimination. The effectiveness of such a binary signature coding largely relies on how well the Hamming distance can capture spectral variations that characterize a signature. Unfortunately, in most cases, such coding does not provide sufficient information for signature analysis, thus it has received little interest in the past. This paper reinvents the wheel by introducing a new concept, referred to as spectral feature probabilistic coding (SFPC) into signature coding. Since the Hamming distance does not take into account the band-to-band variation, it can be considered as a memoryless distance. Therefore, one approach is to extend the Hamming distance to a distance with memory. One such coding technique is the well-known arithmetic coding (AC) which encodes a signature in a probabilistic manner. The values resulting from the AC is then used to measure the distance between two signatures. This paper investigates AC-based signature coding for signature analysis and conducts a comparative analysis with spectral binary coding.

6233-85, Session 17

Comparison of minimum spanning tree reordering with bias-adjusted reordering for lossless compression of 3D ultraspectral sounder data

B. Huang, A. Ahuja, H. A. Huang, Univ. of Wisconsin/Madison; M. D. Goldberg, National Oceanic and Atmospheric Administration

The ultraspectral sounder data features strong correlations in disjoint spectral regions due to the same type of absorbing gases. This paper investigates lossless compression of ultraspectral sounder data using two robust data preprocessing schemes, namely Minimum Spanning Tree (MST) reordering and Bias-Adjusted reordering (BAR). Both schemes can take advantage of the strong correlations for achieving higher compression gains. The compression methods consist of the MST or BAR preprocessing schemes followed by linear prediction with context-free or context-based arithmetic coding. Various cost functions for both MST and BAR schemes are explored. Compression experiments on the NASA AIRS ultraspectral sounder data set show that MST outperforms BAR for context-free arithmetic coding, whereas BAR outperforms MST for context-based arithmetic coding.

6233-86, Poster Session

Adaptive branch and bound algorithm for selecting optimal features in hyperspectral data

S. Nakariyakul, D. P. Casasent, Carnegie Mellon Univ.

We propose a new adaptive branch and bound algorithm for selecting the optimal subset of features in hyperspectral data. An adaptive branch and bound algorithm increases the searching speed by avoiding unnecessary criterion function calculations of nodes in the solution tree. Our adaptive branch and bound algorithm includes: (i) ordering the tree nodes during the tree construction phase, (ii) obtaining a large initial bound by floating search methods, (iii) finding a proper starting search level in the tree, and (iv) using a prediction mechanism to avoid redundant calculations of criterion functions. Our experiment results demonstrate that our method outperforms other versions of branch and bound algorithms for high-dimensional data.

6233-87, Poster Session

Adaptive histogram subsection modification for infrared image enhancement

H. Qu, Q. Chen, Nanjing Univ. of Science & Technology (China)

Firstly, the drawbacks of infrared image histogram equalization and its improved algorithm are analyzed in the paper. A new technique that can both enhance the contrast and hold detail information of infrared image is presented. That is adaptive histogram subsection modification. The property of infrared image histogram is applied to determine the subsection position adaptively. The second order difference of histogram curve is calculated starting from the highest gray level. The first inflexion is chosen as the subsection point between infrared image detail and background in histogram. Then the gray histogram of infrared image detail occupied low ratio of pixels and background occupied high ratio of pixels are modified respectively. The original gray levels are preserved and the details are enhanced simultaneously during expanding the dynamic range of gray levels in infrared image. Also, suitable distance is kept between gray levels in order to avoid large isolated grains defined as patchiness on the image. Finally, Several infrared images are adopted to demonstrate the performance of this method. Experimental results show that the infrared image quality is improved by this approach. Furthermore, the proposed algorithm is simple and easy to be performed.

6233-88, Poster Session

PCA-based image fusion

S. K. S. Sadhasivam, St. Joseph's College of Engineering (India); M. Muthan, Anna Univ. (India)

Image fusion is the combination of two or more different images to form a fused image by using a certain algorithm. In this paper, the algorithm is designed in such a way that extracts the information based on the principal components present in the images.Principal component analysis aims at reducing a large set of variables to a small set that still contains most of the information in the large set. The technique of principal component analysis enables us to create and use a reduced set of variables,which are called principal factors. A reduced set is much easier to analyze and interpret. In this paper, fusion of images obtained from a visible camera and that from an infrared camera is been done.

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6234-01, Session 1

Three-dimensional imaging and recognition of microorganisms using computational holography

B. Javidi, S. Yeom, I. Moon, Univ. of Connecticut; E. M. Carapezza, DARPA and Cochair of DoD/DoJ Joint Program Committee Steering Group

In this Keynote Address, we present three-dimensional (3D) visualization and recognition of microorganisms using single-exposure on-line (SEOL) digital holography. For visualization, a coherent 3D microscope-based Mach-Zehnder interferometer records a single-exposure on-line Fresnel digital hologram of microorganisms. Three dimensional microscopic images are computationally reconstructed at different depths by the inverse Fresnel transformation. For recognition, first, microbiological objects are segmented and then, Gabor-based wavelets extract salient feature vectors from the complex amplitude of holographic images. At the final stage, a graph matching technique localizes predefined 3D morphologies of biological samples. Preliminary experimental results using sphacelaria alga and tribonema aequale alga are presented.

6234-02, Session 1

Multiresolution target manifold characterization for 3D imaging LADAR

E. Whittenberger, D. E. Waagen, N. N. Shah, D. R. Hulsey, Raytheon Missile Systems

Manifold extraction techniques, such as ISOMAP, have been shown to reduce nonlinear, high dimensional data to a native, lower dimensional subspace while retaining discriminatory information. In this investigation, these techniques are applied to 3D LADAR imagery. Using a combination of synthetic and field collected LADAR imagery, selected man-made and natural clutter objects are reduced to stacks of spin image feature vectors that describe object surface geometries. Spin images are discrete versions of the CMU-developed Spin Map representation of 3D data, and have been shown to be robust to occlusion and noise for object classification. At various resolutions, object data manifolds extracted using ISOMAP in this feature space are examined to quantify differences between man-made and clutter object classes.

6234-03, Session 1

Hierarchical searching in model-based LADAR ATR using statistical separability tests

S. P. DelMarco, E. C. Sobel, J. Douglas, BAE Systems Advanced Information Technologies

In this work we investigate simultaneous object identification improvement and efficient library search for model-based object recognition applications. We develop an algorithm to provide efficient, prioritized, hierarchical searching of the object model database. A common approach to model-based object recognition chooses the object label corresponding to the best match score. However, due to corrupting effects the best match score does not always correspond to the correct object model. To address this problem, we propose a search strategy which exploits information contained in a number of representative elements of the library to drill down to a small class with high probability of containing the object. We first optimally partition the library into a hierarchic taxonomy of disjoint classes. A small number of representative elements are used to characterize each object model class. At each hierarchy level, the observed object is matched against the representative elements of each class to generate score sets. A hypothesis testing problem, using a distribution-free statistical test, is defined on the score sets and used to choose the appropriate class for a prioritized search. We conduct a probabilistic analysis of the computational cost savings, and provide a formula measuring the computational advantage of the proposed approach. We generate numerical results using match scores derived from matching highly-detailed CAD models of civilian ground vehicles used in 3-D LADAR ATR. We present numerical results showing effects on classification performance of significance level and representative element number in the score set hypothesis testing problem.

6234-04, Session 1

Using graphical models to segment airborne laser swath map (ALSM) data clouds

J. T. Cobb, Naval Surface Warfare Ctr.; C. Slatton, Univ. of Florida

Graphical models, such as hidden Markov models and Markov random fields, are popular methods to model temporal and spatial dependencies in the states of nature that describe multidimensional data structures. In a graphical model, each data point or state represents a discrete random variable. The links between nodes describe relationships between the different random variables within the graph topology.

A segmentation method of multidimensional airborne laser swath map data based on graphical model representation is presented. An ALSM system provides a 3-D cloud of points in elevation, range, and cross-range. By projecting the ALSM data onto a grid of nodes, a graphical model becomes a natural way to encode the spatial dependencies between nodes. The random variables at each node describe a state of nature in the cloud such as whether a certain area of terrain is trafficable or contains obstacles. Once the probabilities at each node are known, the strength of the correlations between nodes are measured. The correlation measurements yield a structure in the grid that is used for data segmentation. Results of the segmentation method applied to simulated ALSM data is presented.

6234-05, Session 1

Rapid and scalable 3D object recognition using lidar data

B. C. Matei, H. S. Sawhney, Sarnoff Corp.

We propose a new method for rapid 3D object recognition that combines feature based methods with coarse alignment based matching techniques. Our approach achieves a sublinear complexity on the number of models, maintaining at the same time a high degree of performance for real 3D sensed data that is acquired in largely uncontrolled settings. The key component of our method is to first index surface descriptors computed in the scene into the whole model database using the Locality Sensitive Hashing (LSH), an approximate nearest neighbor method. Progressively complex geometric constraints are subsequently enforced to further prune the initial candidates and eliminate false correspondences due to inaccuracies in the surface descriptors and the errors of the LSH algorithm.

Models having a high degree of similarity in shape with the target are finally identified by verifying certain saliency tests which are learned offline and can maximize an objective discriminative criterion.

6234-06, Session 1

Model-based target detection and recognition with ladar imagery

S. K. Ralph, C. S. Monnier, M. S. Snorrason, Charles River Analytics, Inc.

Most current Model-Based LADAR Automatic Target Recognition (ATR) proceeds in two phases: a detection phase, that segments data points into foreground and background according to their departure from the ground plane; and a recognition step that considers a set of pose hypotheses, and iteratively refines the pose to obtain a match score reflect-ing the best estimate. This score is then used to rank one model hypothesis over another. The detection phase is chal-lenging since noise in the LADAR imagery produces a large number of points that appear to depart from the ground-plane, and must be further filtered (e.g. by cluster size) to reduce the number of false-detections. The recognition phase is challenging since it must consider a large number of model hypotheses to ensure correct recognition. Additionally, a large number of poses must be considered in order to ensure that correct alignment is recovered, as incorrect alignment will lead to erroneous match scores.

To address these two challenging aspects of the ATR problem we propose a detection and recognition strategy that ef-fectively detects targets with few false alarms, and quickly recovers the pose of the target using a set of local image fea-tures called spin-images. The target detection algorithm quickly identifies targets that have significant vertical surfaces, a property of most commonly encountered military targets. As vertical surfaces arise from salient and pronounced fea-tures of the targets themselves, they do not give rise to as many false detections as naïve segmentations based on the ground plane.

The ATR phase uses spin-images that capture the local curvature information in a small neighborhood of a target to compute point correspondences on a target model. This process is repeated for multiple spin image features, and then combined into a single pose estimate. For efficiency and accuracy we compute a set of constraints on the image feature correspondences that ensure the best pose is a rigid-body transformation of the model. We also identify instances where symmetry in the model produces ambiguous spin-images.

The overall algorithm has been shown to be efficient in identifying the correct target, and has been shown to be robust with respect to occlusion and clutter.

6234-07, Session 1

Minimum probability of error recognition of three-dimensional laser-scanned targets

M. D. DeVore, X. Zhou, Univ. of Virginia

Shape measurements form powerful features for recognizing objects, and many imaging modalities produce three-dimensional shape information. Stereo-photogrammetric techniques have been extensively developed, and many researchers have looked at related techniques such as shape from motion, shape from accommodation, and shape from shading. Recently considerable attention has focused on laser radar systems for imaging distant objects, such as automobiles from an airborne platform, and to laser-based active stereo imaging for close-range objects, such as face scanners for biometric identification. Each use of these laser imagers generally results in a range image, an array of distance measurements as a function of direction. For multi-look data or data fused from multiple sensors, we may more generally treat the data as a 3D point-cloud, an unordered collection of 3D points measured from the surface of the scene. We formulate a general approach to recognition suitable for application to a wide range of 3D imaging systems. The approach relies on a probabilistic framework relating 3D point-cloud data and the objects from which they are measured. Through this framework we derive a minimum probability of error recognition algorithm that allows for arbitrary (range and cross-range) measurement errors. We apply the algorithm in a problem of target recognition from actual 3D point-cloud data measured in the laboratory from scale models of civilian vehicles. We demonstrate the use of noisy 3D measurements to train models of the targets and the use of these models for classification. We discuss implementation issues in both training and recognition stages, relating accuracy and computational complexity to the resolution of trained models. We demonstrate that high correct recognition rates can be obtained between vehicles with similar body styles, even when low-resolution models are employed. Finally, we address the presence of nuisance parameters including segmentation of background measurements and recognition in the presence of pose uncertainty.

6234-08, Session 1

A statistical analysis of 3D structure sensors generated from LADAR imagery

M. A. Ordaz, D. R. Hulsey, D. E. Waagen, Raytheon Missile Systems

Classification of targets is traditionally implemented through characterization of target features that retain unique target information. The multitude of choice features are seldom statistically analyzed for distributional separation. The goal being that if a battery of distance measure tests cannot quantitatively separate feature distributions from distinct target or clutter distributions then the feature or features being extracted would be deemed irrelevant. This paper analyzes the statistical distributions generated by features extracted from 3-D LADAR imagery that could ultimately be used for target matching and recognition. 3-D structure tensors are extracted by mapping surface geometries using a rank-2 co-variant tensor. The idea is to extract local surface shape descriptors from point cloud data that should uniquely identify targets. The surface descriptors are analyzed using traditional statistical methodologies for measuring separation of target and clutter feature densities.

6234-09, Session 2

Genetic algorithm based composite wavelet-matched filter for 0 to 360 degree out-of-plane rotations for target recognition

A. K. Gupta, N. K. Nishchal, V. K. Beri, Instruments Research and Development Establishment (India)

In this paper, we describe and implement a genetic algorithm based composite wavelet-matched filter for target recognition. The designed filter is invariant to 0-to-360° out-of-plane rotation ranges. The Mexican-hat wavelet has been used for the design of the filter. Genetic algorithm, which is a search algorithm based on the mechanics of natural selection and natural genetics, has been used to optimize the weight factors for the input matched filters and the different scale wavelets. The designed filter is implemented in the hybrid digital-optical correlator architecture. The input scene/target is recorded in real-time using a CCD/thermal camera. The target's Fourier spectrum is calculated digitally and the generated filter is multiplied with this spectrum. This multiplied product is basically a complex valued function, which is encoded into a binary amplitude or phase function for further optical processing. The encoded multiplied product function is displayed onto a ferroelectric liquid crystal spatial light modulator for obtaining the optical Fourier transformation after illuminating with a coherent collimated light beam from a laser diode. In the output plane, two bright sharp spots +1 and -1 diffraction orders, corresponding to two autocorrelation peaks, along with a strong dc (zero-order) are obtained, when the filters are correlated with trained images belonging to the true class. For false class images no peaks are obtained. Simulation and experimental results in support of the proposed idea are presented.

6234-10, Session 2

Automated target detection and recognition in the process of interaction between visual and object buffers of scene understanding system based on network-symbolic models

G. Kuvich, Smart Computer Vision Systems

Modern computer vision systems lack human-like abilities to understand visual scene and detect and unambiguously identify and recognize objects. Although they can recognize certain features from visual information perfectly well, it can play an auxiliary role in the real vision. Bottom-up grouping can rarely be effective for real world images if applied to the whole image without having clear criteria of how further to combine obtained small distinctive neighbor regions into meaningful objects. ATR systems that are based on the similar principles become dysfunctional if target doesn't demonstrate remarkably distinctive and contrast features that allows for unambiguous separation from background and identification upon such features. However, human vision unambiguously separates any object from its background and recognizes it, using for that rough but wide peripheral system that tracks motions and regions of interests, and narrow but precise foveal vision that analyzes and recognizes object in the center of selected region of interest, and visual intelligence that provides scene and object contexts and resolves ambiguity and uncertainty in the visual information. Biologically-inspired Network-Symbolic models convert image information into an "understandable" Network-Symbolic format, which is similar to relational knowledge models. The equivalent of interaction between peripheral and foveal systems in the network-symbolic system is achieved via interaction between Visual and Object Buffers and top-level knowledge system. This interaction provides recursive rough context identification of regions of interest in the visual scene, and their analysis in the object buffer for precise and unambiguous separation of the target from clutter with following recognition of the target.

6234-11, Session 2

Nonimaging detection of target shape, size, and pose

S. M. Chandler, G. W. Lukesh, Nukove Scientific Consulting, LLC

For nearly a decade, Susan Chandler and Gordon Lukesh, through funding by AFRL and AFOSR, have studied the use of data contained in the received time-series signal from ground-to-space laser illumination experiments carried out at Starfire Optical Range (Kirtland AFB) and AMOS (Maui). The capability to obtain gross target information without the need for costly imaging systems or adaptive optics, offers a cost-effective method for both strategic and tactical uses. This paper describes the key chi-square approach using predetermined simulated data. Through funding by AFOSR, Nukove is developing a software tool RHINO (Real-time Histogram Interpretation of Numerical Observations) that offers the potential for reasonably inexpensive observation of long range targets.

6234-12, Session 2

A new methodology for target recognition and reconstruction of moving rigid-body targets

S. Fazio, Defense Acquisition Univ.; L. Hong, Wright State Univ.

This paper presents a novel methodology for target recognition and reconstruction of rigid body moving targets. Traditional methods such as Synthetic Aperture Radar (SAR) rely on information gathered from multiple sensor locations and complex processing algorithms. Additional processing is often required to mitigate the effects of motion and improve the image resolution. Many of these techniques rely on information external to the target such as target radar signatures and neglect information available from the structure of the target, structural invariance, and kinematics. This revolutionary target reconstruction method incorporates information not traditionally used. As a result the absolute position of two, target scattering centers can theoretically be determined with external high resolution radar range information from three observations of two target scattering centers. Relative motion between the target and the sensor and structural invariance provides additional information for determining position of the target's scattering center, actual scaling, and angular orientation with respect to the sensor for reconstruction and imaging.

This methodology is based on the kinematics of rotational motion resulting from relative movement between the sensor and the target. External range data provides one-dimensional information for determining position in a two-dimensional projection of the scattering centers. The range location of the scattering center, relative to a defined center, is analyzed using rotational motion. Range and target kinematics support the development of a conceptual model. Actual scaling and the target's orientation with respect to the sensor are developed through a series of trigonometric relationships. The resulting three-dimensional coordinates for the scattering centers are then used for target reconstruction and image enhancement.

6234-13, Session 2

Model-based recognition using 3D invariants and stereo imaging

M. T. Rahman, M. S. Alam, Univ. of South Alabama

In this paper, we proposed a three dimensional matching algorithm using geometrical invariants. Invariant relations between 3D objects and 2D images for object recognition has been already developed in Ref. [1]. We proposed a geometrical invariant approach for finding relation between 3D model and stereo image pair. Since the depth information is lost in a single 2D image, we cannot recognize an object perfectly. By constructing a 3D invariant space we can represent a 3D model as a set of points in the invariant space. While matching with the 2D image we can draw a set of invariant light rays in 3D, each ray passing through a 3D invariant model point. If enough rays intersect the model in 3D invariant space we can assume that the model is present in the image. But for a single image the method is not that much reliable as the depth information is never considered. In the proposed method, as the matching is performed using stereo image pair, it is more reliable and accurate.

6234-14, Session 3

Subdivision of training image sets for composite correlation filter banks

D. W. Carlson, A. Ramirez, N. N. Shah, D. E. Waagen, Raytheon Missile Systems

Composite correlation filters have been demonstrated in many automatic target recognition (ATR) applications because of their ability for class discrimination and distortion-tolerance with shift invariance. By combining a subset of the training images into each filter, the filter bank can recognize a target class across distortions such as target pose (azimuth). However, the selection of training images for each filter in the bank is usually a simple approach resulting in variable performance across filters. We investigate a new use of Isometric Mapping (ISOMAP) manifold extraction and spanning trees to group the training images for use in composite correlation filter approaches to imaging infrared ATR. ISOMAP is a nonlinear method that reduces the high dimensionality of data such as images. Other methods of selecting the training sets in a filter bank including equally-spaced and cross-correlation are compared in their impact on target classification. Test results using the public released AMRDEC database are shown.

6234-15, Session 3

Adaptive determination of Eigenvalues and Eigenvectors from perturbed autocorrelation matrices for automatic target recognition

P. Ragothaman, W. B. Mikhael, Univ. of Central Florida; R. R. Muise, A. Mahalanobis, Lockheed Martin Missiles and Fire Control; T. C. Yang, Embry-Riddle Aeronautical Univ.

The Modified Eigenvalue problem arises in many applications such as Array Processing, Automatic Target Recognition (ATR), etc. These applications usually involve the Eigenvalue Decomposition (EVD) of matrices that are time varying. It is desirable to have methods that eliminate the need to perform an EVD every time the matrix changes but instead update the EVD adaptively, starting from the initial EVD. In this paper, we propose a novel Optimal Adaptive Algorithm for the Modified EVD problem (OAMEVD). Sample results are presented for an ATR application, which uses Rayleigh Quotient Quadratic Correlation filters (RQQCF). Using simple synthetic and real Infrared (IR) datasets, the effectiveness of this new technique as well as its advantages are illustrated.

6234-16, Session 3

Target detection using texture operators

J. M. Coggins, BAE Systems Advanced Information Technologies

Target detection in SAR is demonstrated using multiscale texture features in a Spatial Spectroscopy framework on MSTAR full-scene imagery. Initial description of image structure is obtained using an approximation to the multiscale N-jet (Taylor Series expansion truncated at order N) at each pixel. The approximation involves multiscale Gaussian filters and shifted versions of those filters, with the shift proportional to scale. Texture is average local energy through scale and orientation, so the main features describing location x are the absolute differences between the blurred intensities at x and nearby offset locations at scale s and the intensity at location x at larger scale s+1. We find that targets can be detected by identifying points whose texture differs maximally from the texture of the image background. Results, including ROC curves, obtained on MSTAR full-scene SAR images (targets-in-the-clear) are reported. Preliminary results on target detection with clutter are also reported.

6234-17, Session 3

Improved target detection algorithm using Fukunaga-Koontz transform and distance classifier correlation filter

A. Bal, M. S. Alam, Univ. of South Alabama

Often sensor ego-motion or fast target movement causes the target to temporarily go out of the field-of-view leading to reappearing target detection problem in target tracking applications. Since the target goes out of the current frame and reenters at a later frame, the reentering location and variations in rotation, scale, and other 3D orientations of the target are not known thus complicating the detection and tracking of reappearing targets. In this paper, a new training based target detection algorithm has been developed using Fukunaga-Koontz Transform (FKT) and distance classifier correlation filter (DCCF). The detection algorithm uses target and background information, extracted from training samples, to detect possible candidate target images. The detected candidate target images are then introduced into the second algorithm, DCCF, called clutter rejection module, to determine the target reentering frame and location of the target. If the target reenters the current frame, target coordinates are detected and tracking algorithm is initiated. The performance of the proposed FKT-DCCF based target detection algorithm has been tested using real-world forward looking infrared (FLIR) video sequences.

6234-18, Session 3

Implementation of three-dimensional linear phase coefficient composite filter for head pose estimation

D. S. Woon, L. G. Hassebrook, D. L. Lau, Z. Wang, Univ. of Kentucky

The use of 3-Dimensional information in face recognition requires pose estimation. We present the use of 3-Dimensional composite correlation filter to obtain pose estimation without the need for feature identification. Composite correlation filter research has been vigorously pursued in the last three decades due to their applications in many areas, but mainly in distortion-invariant pattern recognition. While most of this research is in two-dimensional space, we have extended our study of composite filters to three-dimensions, specifically emphasizing Linear Phase Coefficient Composite Filter (LPCCF). Unlike previous approaches to composite filter design, this method considers the filter design and the training set selection simultaneously. In this research, we demonstrate the potential of implementing LPCCF in head pose estimation. We introduce the utilization of LPCCF in the application of head pose recovery through full correlation using a set of 3-D voxel maps instead of the typical 2-D pixel images/silhouettes. Unlike some existing approaches to pose estimation, we are able to acquire 3-D head pose without locating salient features of a subject. In theory, the correlation phase response contains information about the angle of head rotation of the subject. Pose estimation experiments are conducted for two degrees of freedom in rotation, that is, yaw and pitch angles. The results obtained are very much inline with our theoretical hypothesis on head orientation estimation.

6234-19, Session 3

Binary phase-only reference for invariant pattern recognition with the joint transform correlator

J. A. Butt, T. D. Wilkinson, Univ. of Cambridge (United Kingdom)

The joint transform correlator (JTC) is one of the two main optical image processing architecture which provides a highly effective way of comparing images in a wide range of applications. Traditionally an optical correlator is used to compare an unknown input scene with a pre-captured reference image library, to detect if the reference occurs within the input. Strength of the correlation signal decreases rapidly as the input object rotates or varies in scale relative to the reference object. The aim is to overcome the intolerance of the JTC to rotation and scale changes in the target image. Many JTC systems are constructed with the use of ferroelectric liquid crystal (FLC) spatial light modulators (SLMs) as they provide fast two dimensional binary modulation of coherent light. Due to the binary nature of the FLC SLMs used in the JTC systems, any image addressed to the device need to have some form of thresholding. Carefully thresholding the grey scale input plane and the joint power spectrum (JPS) has significant effect on the quality of correlation peaks and zero order (DC) noise. A new thresholding technique to binarise the JPS has been developed and implemented optically. This algorithm selectively enhances the desirable fringes in the JPS which provide correlation peaks of higher intensity. Zero order noise is further reduced when compared to existing thresholding techniques.

Keeping in mind the architecture of the JTC and limitations of FLC SLMs, a new technique to design rotation and scale invariant binary phase only reference image for the JTC architecture is presented. Reference design with this technique has limited dynamic range, higher discriminability among target and non-target objects, and convenience for implementation on FLC SLMs. Simulation and experiments shows excellent results of various rotation and scale invariant references designed with this technique. A rotation invariant reference is needed for various machine vision applications of the JTC. By fixing the distance between camera and input object, the scale sensitivity of the correlator can be avoided. In contrast to the industrial machine vision applications, scale factor is very important factor for the applications of the JTC systems in Defense and security. A security system using a scale invariant JTC will be able to detect a target object well in advance and will provide more time to take a decision.

6234-20, Session 3

Effect of convolution and modulation on the time-varying spectrum of a signal with application in target recognition

P. J. Loughlin, Univ. of Pittsburgh

In active sonar or radar, the received signal can often be modeled as a convolution of the transmitted signal with the channel impulse response and the target impulse response. Because the received signal may have a time-varying spectrum, due for example to target motion or to changes in the channel impulse response, time-frequency methods have been used to characterize propagation effects and target effects, and to extract features for classification. In this presentation, we consider the time-varying spectrum, in particular the Wigner time-frequency representation, of a received signal modeled as the convolution of the transmitted signal with the channel and target responses. We derive a simple but very insightful approximation that shows the effects of the magnitude and phase of the frequency response of the target and of the channel on the Wigner representation of the transmitted signal. We also consider time-varying effects on the Wigner representation, such as changes in reflected energy due to changes in aspect angle, which we model by amplitude modulation.

6234-21, Session 4

Human detection and tracking

M. A. Shah, Univ. of Central Florida

Abstract not available

6234-22, Session 4

Real-time pre-ATR video data reduction in wireless networks

T. P. Jannson, A. A. Kostrzewski, Physical Optics Corp.

While a lot of papers have been published in the area of ATR and pattern recognition, only a few have been focused on real-time automated data reduction for moving objects from video streams, obtained from UGVs, UAVs, and other moving platforms, operating within RF wireless video networks. One of the critical subjects for home security is identifying moving targets by more than two moving cameras with more than one target of interest. Such a target identification (ID), in real-time, in terms of its location, motion vector, distance, size and aspect ratio, is necessary for further ATR, which can be provided by more conventional means.

In this paper, we propose a simple method of moving target ID in real-time, based on statistical flow motion evaluation, by applying supercomputer-in-a-box hardware and related software that uses only simple arithmetic computations. For such purposes, the new motion-error firmware is applied that provides pixel-by-pixel subtraction in real-time, including GPS and automated azimuth and spead vector evaluatons for each UGV and camera of interest. In addition, the video sensor RF network provides cooperative/interactive data transfer, including: optimized Peak-Signl-to-Noise-Ratio (PSNR) performance and synchronized video frame search,based on metadata, time stamps, and so-called Meaningful I-frames, or M-frames. The proposed method is needed for effective real-time ATR of moving targets in such applications as: border patrol, railroad stations/ports monitoring, physical security, and many others.

6234-23, Session 4

Efficient image estabilization and automatic target detection in aerial FLIR sequences

E. Estalayo, L. Salgado, N. N. García, F. Jaureguízar, Univ. Politécnica de Madrid (Spain)

This paper presents a system which automatically detects moving targets contained in aerial sequences of FLIR images under heavy cluttered conditions. In these situations, the detection of moving targets is generally carried out through the implementation of segmentation and tracking techniques based on the images correlation maintained by the static camera hypothesis [1]. However, detection procedures cannot rely on this correlation when the camera is being transported and, therefore, image stabilization techniques are usually introduced previously to the detection process [2]. Nevertheless, the related work, incorporating the use of stabilization algorithms, has been often applied to terrestrial sequences and assuming a high computational cost [3]. To overcome these limitations, we propose an innovative and efficient strategy, with a block-based estimation and an affine transformation for recovering from the ego-motion, which operates on a multi-resolution approach. This strategy deepens into the work by Seok [4], minimizing its implicit limitations, derived from an oversimplified rotation model which combines rotational and translational motions. The novelty of our strategy relies on the relaxation of the assumed hypothesis and, hence, on the enhancement of its applicability, by overcoming the imposition of having rotational displacements within the camera motion; and also by further reducing its computational cost, thanks to the application of a multi-resolution algorithm in which the stabilization technique is applied on the lowest resolution image. Next, once the images have been compensated on the highest resolution image and refined to avoid distortions produced in the sampling process, a dynamic differences based segmentation followed by a morphological filtering strategy is applied. The experiments performed have obtained excellent results and, although the complexity of the system arises, the application of the multi-resolution approach has proved to dramatically reduce the global computational cost.

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6234-24, Session 4

Target detection in FLIR imagery using independent component analysis

A. Sadeque, M. S. Alam, A. Bal, Univ. of South Alabama

In this paper, we propose a target detection algorithm in FLIR imagery using independent component analysis (ICA). Here FLIR images of some real targets with practical background regions are used for training. Dimension of the training regions is chosen depending on the size of the target. After performing ICA transformation on these training images, we obtain an ICA matrix (U), where each row gives the transformed version of the previous matrix, and a mixing matrix (W). Using these matrices, a transformed matrix of the input image can be found with enhanced features. Then cosine of the angle between the training and test vectors is employed as the parameter for detecting the unknown target. A test region is selected from the first frame of FLIR image, which is of the same size as the training region. This region is transformed following the proposed algorithm and then the cosine value is measured between this trans-

formed vector and the corresponding vector of the transformed training matrix. Next the test region is shifted by one pixel and the same transformation and measurement are done. Thus the whole input frame is scanned and we get a matrix for cosine values. Finally a target is detected in a region of the input frame where it gives the highest cosine value which is very close to unity. A detailed computer simulation program is developed for the proposed algorithm and a satisfactory performance is observed when tested with real FLIR images.

6234-25, Session 4

Multifractal simulation of atmospheric turbulence for long-distance surveillance in the infrared

J. Blanc-Talon, M. Lemaitre, Ctr. d'Expertise Parisien (France)

Atmospheric perturbation is certainly the most important degradation in ground to ground surveillance applications from a distance of several kilometres. Assuming videos are recorded with a normal exposure time (i.e the turbulence is not "frozen"), we studied how to make turbulence simulation and video restoration compatible for computing new turbulence parameters and enhancing video restoration.

The first part of the paper is devoted to a couple of simulation processes: first, a classical simulation algorithm is detailed and adapted to both anisoplanatic and isoplanatic cases; second, a new multifractal-based approach is detailed. Simulations have been made with different ratios D/r0 corresponding to different turbulence intensity values in the infrared. Moreover the generation of image sequences where the temporal evolution of the atmospheric turbulence for a fixed scene (i.e. without camera motion) is taken into account, is studied.

In the second part of this paper, different classical restoration methods have been evaluated on several sequences: inverse filtering, Tikhonov regularization, Laplacian regularization, and Wiener filtering. These four methods can only be used with single frames and also require some a priori knowledge about the original image. To overcome this limitation, a more recent method called "Windowed-Wiener" has been evaluated on the test images as well. Comparisons have been made between the different computed results.

6234-26, Session 4

AKSED: adaptive knowledge-based system for event detection using collaborative unmanned aerial vehicles

X. S. Wang, B. S. Lee, The Univ. of Vermont; F. A. Sadjadi, Lockheed Martin Corp.

During the past several decades, advances in sensor technology and image processing have made it possible to apply sensors to detect targets that are fixed or moving under a variety of environmental conditions. Moreover, as sensors are becoming miniaturized and

their production costs reduced, it has become increasingly feasible to equip UAVs with

economical, high-resolution, energy-efficient sensors. Despite the continuous improvements, current UAVs lack autonomous and collaborative operation capabilities,

due to limited bandwidth and limited on-board image processing abilities. The situation, however, is changing. In the next generation of UAVs, much image processing can be carried out onboard and communication bandwidth problem will improve. More

importantly, with more processing power, collaborative operations among a team of autonomous UAVs can provide more intelligent event detection capabilities. In this paper, we present ideas for developing a system enabling target recognitions by collaborative

operations of autonomous UAVs.

6234-44, Session 4

Toward practical pattern-theoretic ATR algorithms for infrared imagery

J. A. Dixon, A. D. Lanterman, Georgia Institute of Technology

A decade ago, work began on applying Grenander's pattern theory to the problem of automatic target recognition from infrared imagery. Underlying configurations of targets are represented by parameter spaces with varying dimension. The ability to simulate infrared scenes lies at the core of the Grenander approach, as hypothesized scenes are compared to the collected data via a sensor likelihood function. Random sampling algorithms are attractive for drawing inferences from the resulting Bayesian posterior distribution.

Previously explored random sampling algorithms, based on jump-diffusion processes, have been shown to be sensitive to implementation choices of the step sizes used in the discretization of the diffusion process, as well as the step sizes used to numerically compute derivatives. The extensive tuning required, which varies between target types, limits the practicality of such algorithms. Hence, we consider alternative algorithms that facilitate local parameter search via Metropolis-Hastings or Gibbs style sampling in a small region around the current parameter estimate.

Targets in infrared images will take on vastly different appearances depending on their individual thermal states, even if they are the same kind of target. We accommodate this thermal variability using sums of "eigentanks" derived from thermodynamic simulation software. The eigentanks are defined over the full surface of the target. The coefficients multiplying the eigentanks represent nuisance parameters that must be co-estimated or integrated out. Previous explorations of this approach have focused on simplified single-target examples; this is the first work to incorporate this method in the multiple-target case.

6234-27, Session 5

MSTAR object classification and confuser and clutter rejection using MINACE filters

R. Patnaik, D. P. Casasent, Carnegie Mellon Univ.

We present an automatic target recognition system (ATR) for SAR data based on the minimum noise and correlation energy (MINACE) distortion-invariant filter (DIF). We use a subset of the Moving and Stationary Target Acquisition and Recognition (MSTAR) public dataset for three-class object classification and we address confuser and clutter rejection. To handle the full 360° range of aspect view in MSTAR data, we use a set of MINACE filters for each object. Each filter should recognize test set images of the filter's object (and its variants) in the filter's angular range. Our filter synthesis algorithm automatically selects the MINACE filter parameter c and the training set images included in the filter. The MINACE filters for each object are a combination of training set images of only that object; they do not contain any images of other objects, i.e., no false-class training is done, since that can produce biased results. In our new filter synthesis, no confuser, clutter, or test set data are used. We also address use of fewer DIFs per object than prior work did. The peak-to-correlation energy (PCE) ratio is used as the correlation plane metric in filter synthesis and in testing, since it works better than correlation peak height or the peak-to-sidelobe ratio. In tests, we do not assume that the test inputs' pose are known, thus the problem addressed is more realistic than in prior work, since pose estimation of SAR objects has a large margin of error.

6234-28, Session 5

Interferoceiver, ISAR, and passive identification

M. Li, Consultant

It is widely known to radar engineers that the best radar receiver is a correlation receiver, which correlates the originally transmitted radar pulse with received pulses from the reflection. The time delay from reflection requires that the transmitted pulse be stored while waiting for the return

of reflected pulses. But there was no medium which could faithfully store the transmitted pulse, and the true correlation receiver could not be realized in past. The advancement of fiber optical technology changes that. The new and true correlation receiver based on optical fiber delay loops has been referred to as interferoceiver1.

Current radar receivers are super heterodyne receivers, which require many multiple pulses to measure Doppler beating and lead to Doppler-range ambiguity. With interferoceivers, it becomes possible to measure Doppler beating by a single pulse. Hence there is no Doppler-range ambiguity. This changes the technical foundation of radar.

A barrier in ISAR technology is the Doppler cross range blurring, which is caused by multiple pulses and continuing rotational motion of the target. Since 1980s, many efforts have been devoted to remove the above shortcoming, but with limited success. Now with interferoceivers, the shortcoming is eliminated. We will be able to map out vibrations with Doppler resolution better than 1.0 Hz, and to take sharp ISAR images of targets as far as 100 Km or more.

The theoretical foundation of interferoceiver and related technologies will be reviewed. Then a simulation is given to illustrate the power of interferoceiver in passive identification.

It is a hope that the present talk will inspire the interest on the development of interferoceiver.

Reference:

Ming-Chiang Li, “A High Precision Doppler Radar Based on Optical Fiber Delay Loops”, IEEE Transactions on Antennas and Propagation, 2004, 52, pp. 3319-3328.

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Ming-Chiang Li, “Radar Receivers Based on Correlation Measurements”, IEE Proceedings Radar, Sonar & Navigation, (to be published).

6234-29, Session 5

Bistatic SAR ATR using PCA-based features

A. K. Mishra, B. Mulgrew, Univ. of Edinburgh (United Kingdom)

Airborne bistatic radar has long been recognized as offering advantages as a counter stealth and anti-jamming technology as compared to its monostatic counterpart. Algorithms for bistatic synthetic aperture image formation are now starting to appear in the open literature.

Given the potential of a non-monostatic configuration, bistatic and multistatic configurations may replace or coexist with the present monostatic systems in some existing applications. In any military radar system, a facility for robust automatic target recognition (ATR) facility is desirable. In this paper we present the work, involving a study into the bistatic ATR problem and the application of principal component analysis (PCA) based classification algorithms in bistatic ATR.

There are quite a few dimensions to the novelty of the work in this paper. First of all, the study of performance of ATR algorithms in bistatic scenario, in itself is a novel area. Secondly, the database used for the purpose has been developed completely by indigenous efforts. Thirdly, the preferred ATR algorithm reported in this work, which is PCA based nearest neighbor (PCA-NN) algorithm, also is a novel algorithm in itself. Though PCA has been used for data compression task by remote sensing community, the usage of the same by ATR community has not been found much in open literature. The results obtained from PCA-NN classifiers are compared with the conditional Gaussian model based Bayesian (CGB) classifier, which has been reported to be of excellent performance for monostatic ATR.

In comparison of the algorithms, three parameters have been taken into account, viz. the absolute performance in the terms of percentage of correct classification, the receiver characteristic curves (ROC) for the two algorithms, and the performance of the algorithms with reduced training data set (which is of paramount importance in bistatic scenario, where obtaining exhaustive dataset is a major problem).

Given the performance of the classifiers on the synthetic database, it was concluded that ATR is a possible candidate for bistatic usages, and the new PCA-NN algorithm was found to be an algorithm of choice for bistatic ATR.

6234-30, Session 6

Recognition of UWB radar targets

I. I. Jouny, Lafayette College

This paper extends the generalized likelihood ratio test to recognize targets interrogated by an ultra wideband radar. UWB radar targets may vary in impulse response duration depending on the electrical size of the target and its aspect angle. This dictates the use of a generalized likelihood ratio test that can be maximized over the data lengths that better distinguishes unknown targets. This study will use real UWB radar data recorded indirectly via a stepped frequency radar over a wideband. Results will be compared with classifiers assuming fixed target tarnsient response.

6234-31, Session 6

Advances in Doppler recognition for ground moving target indication

P. G. Kealey, M. Jahangir, QinetiQ Ltd. (United Kingdom)

Ground Moving Target Indication (GMTI) radar provides a day/night, all-weather, wide-area surveillance capability to detect moving targets. Current GMTI radar sensors are limited to detecting and tracking targets. The exploitation of a GMTI sensor will be greatly enhanced through the provision of a capability to recognise accurately the detections as significant classes of vehicle. Doppler classification exploits the differential internal motion of targets due to the tracks, limbs and rotors for tracked, personnel and helicopter classes respectively.

Recently, the QinetiQ Bayesian Doppler classifier has been extended to include a helicopter class in addition to wheeled, tracked and personnel classes. This paper presents the performance for these four classes using a traditional low-resolution GMTI surveillance waveform with an experimental radar system. We have determined the utility of an ?unknown output decision? for enhancing the accuracy of the declared target classes. A confidence method has been derived to assign uncertain classifications into an ?unknown class?. The trade between fraction of targets declared and accuracy of the classifier has been measured. To determine the operating envelope of a Doppler classification algorithm requires a detailed understanding of the Signal-to-Noise Ratio (SNR) performance of the algorithm. In this study the SNR dependence of the QinetiQ classifier has been determined.

6234-32, Session 6

New experiments in the use of support vector machines in polarimetric radar target classification

F. A. Sadjadi, Lockheed Martin Corp.

Support vector machines are statistical learning methods that have shown improved performance in both classification accuracy and computational complexity in a number of pattern recognition applications. In this paper we explore their utility in the classification of ground based targets by means of fully polarimetric radar. Experimental results using synthetic aperture radar data are provided and a comparison of their performance with the results of a number of other classification techniques is made

6234-46, Session 6

High-frequency sparse array synthesis for target identification signatures

M. A. Hussain, U.S. Army Armament Research, Development and Engineering Ctr.

It is known that high frequency in the terahertz (THz) range have some unique advantages. They have high reflective properties for biological objects and have a good penetration property through dielectric materials. These radiations are non-ionizing and can be used for civilian applications. High frequency aperture consisting of THz transmission modules can be fairly small allowing the equipment to be portable. Phased array components mainly consist of sources detectors up-converters down-converters mixers and circulators. These components, for THz applications, are under active development. However each component of these high frequency modules for transmission and reception can be fairly large. In this paper thinned phased arrays have been investigated. A deterministic approach involving space tapering using Taylor synthesis for continuous aperture has been used. Discretization has been carried out and performance of these arrays has been evaluated for various sidelobe controls. Circular as well as elliptical arrays have been considered. Using the results of thinned circular discrete array elements, elliptical arrays have been designed using invariant principal of the synthesis and their performance evaluated. Use of these arrays for generation of signatures for target identification has been indicated.

6234-33, Session 7

Comparison of optimization-algorithm based feature extraction from time data or time-frequency data for target recognition purposes

H. C. Strifors, S. Abrahamson, T. Andersson, Swedish Defence Research Agency (Sweden); G. C. Gaunaurd, Army Research Lab.

Ultra-wideband ground penetrating radar (GPR) systems are useful for extracting and displaying information for target recognition purposes. Target signatures whether in the time, frequency or joint time-frequency domains, will substantially depend on the target's burial conditions such as the type of soil, burial depth, and the soil's moisture content. That dependence can be utilized for target recognition purposes as we have demonstrated previously, using a methodology and algorithm we have developed. The signature template of each target was computed in the time-frequency domain from the returned echo when the target was buried at a known depth in the soil with a known moisture content. Then, for any returned echo the relative difference between the likewise computed target signature and a selected signature template was computed. Using a global optimization method together with our target translation method (TTM) that signature difference, chosen as object function was then minimized by adjusting the depth and moisture content, now taken to be unknown parameters. The template that gave the smallest value of the minimized object function for the returned echo was taken as target classification and the corresponding values of the depth and moisture parameters as estimates of the target's burial conditions. This optimization technique can also be applied to time-series data, avoiding the need for time-frequency analysis. It is then of interest to evaluate the relative merits of time data and time-frequency data for target recognition. Such a comparison is here performed using signals returned from mines or mine-like targets buried underground. The results of the analysis serve to assess the intrinsic worth of data in the time domain and in the time-frequency domain for identifying subsurface targets using a GPR.

6234-34, Session 7

Image database generation using image metric constraints: an application within the CALADIOM project

S. Landeau, T. Dagobert, Ctr. d'Expertise Parisien (France)

Performance assessment and optimization of ATR systems poses the problem of developing image databases for learning and testing purposes. An automatic IR image database generation technique is presented in this paper. The principle consists in superimposing segmented background, target and mask (bushes for example) from real images, under the constraint of predefined image characterization metrics. Each image is automatically computed according to a specification which defines the metrics levels to reach, such as the local contrast Delta T RSS (NVESD metric), the Signal to Clutter Ratio, or the masking ratio target/mask. An integrated calibrated sensor model simulates the sensor degradations by using the pre and post-filter MTF, and the 3D noise parameters of the camera. The image generation comes with the construction of a ground truth file which indicates all the parameter values defining the image scenario. A large quantity of images can be generated accordingly, leading to a meaningful statistical evaluation. A key feature is that this technique allows to build learning and test databases with comparable difficulty, in the sense of the chosen image metrics. The theoretical interest of this technique is presented in the paper, compared to the classical ones which use real or simulated datas. An application is also presented, within the CALADIOM project (terrestrial target detection with programmable artificial IR retina combined with IR ATR system). 10,000 images were processed by this ATR for training and testing, involving seven armored vehicles as targets.

6234-35, Session 7

Development of scale model imagery for ATR investigations

J. M. Irvine, S. M. Bergeron, N. T. Delp, D. R. Lewis, Science Applications International Corp.

Automated target recognition (ATR) methods hold promise for rapid extraction of critical information from imagery data to support military missions. Development of ATR tools generally requires large amounts of imagery data to develop and test algorithms. Deployment of operational ATR systems requires performance validation using operationally relevant imagery. For early algorithm development, however, restrictions on access to such data is a significant impediment, especially for the academic research community. To address this limitation, we have developed a set of grayscale imagery as a surrogate for panchromatic imagery that would be acquired from airborne sensors. This surrogate data set consists of imagery of ground order of battle (GOB) targets in an arid environment. The data set was developed by imaging scale models of these targets set in a scale model background. The imagery spans a range of operating conditions and provides a useful image set for initial explorations of new approaches for ATR development.

6234-36, Session 7

One-dimensional fractal error metric for motion detection in an image sequence

B. S. Allen, L-3 Communications Cincinnati Electronics, Inc; D. Jansing, The Aerospace Corp.

A novel approach to motion detection in an image sequence is presented. This new approach computes a one-dimensional version of the fractal error metric applied temporally across each pixel. The original fractal error algorithm was developed by Cooper et al.[1] as a two-dimensional metric for detecting man-made features in a single image using only spatial information. The fractal error metric is based on the observed propensity of natural image features to fit a fractional Brownian motion (fBm) model, thus producing a small fractal error. On the other hand, man-made features do not fit this model well and therefore produce a larger fractal error. Jansing et al.[2] showed that edges typically do not fit the fBm model due to their irregularity. The 1-D implementation of the algorithm presented in this paper exploits the irregularity of edges in a 1-D temporal signal, which are typically caused by moving objects. Emphasis is placed on moving target detection in the presence of noise and clutter-induced motion. Results are demonstrated using mid-wave infrared image sequences

[1] B. Cooper, D. Chenoweth, and J. Selvage, "Fractal error for detecting man-made features in aerial images", Electronics Letter, vol. 30, no. 7, pp. 554-555, 1994.

[2] E. D. Jansing, B. Allen, D. Chenoweth, "Edge enhancement using the fractal error metric", Proceedings of the 1st International Conference on Engineering Design and Automation, Bangkok, Thailand, March 1997.

6234-37, Session 7

Evaluation testbed for ATD performance prediction (ETAPP)

S. K. Ralph, Charles River Analytics, Inc.; J. M. Irvine, Science Applications International Corp.; M. R. Stevens, M. S. Snorrason, Charles River Analytics, Inc.

Automatic target detection (ATD) systems process imagery to detect and locate targets in imagery in support of a variety of military missions. Accurate prediction of ATD performance would assist in system design and trade studies, collection management, and mission planning. A need exists for ATD performance prediction based exclusively on information available from the imagery and its associated metadata. We present a predictor based on image measures quantifying the intrinsic ATD difficulty on an image. The modeling effort consists of two phases: a learning phase, where image measures are computed for a set of test images, the ATD performance is measured, and a prediction model is developed; and a second phase to test and validate performance prediction. The learning phase produces a mapping, valid across various ATR algorithms, which is even applicable when no image truth is available (e.g., when evaluating denied area imagery). The testbed has plug-in capability to allow rapid evaluation of new ATR algorithms. The image measures employed in the model include. Statistics derived from a constant false alarm rate (CFAR) processor, the Power Spectrum Signature, and others. We present a performance predictor using a trained classifier ATD that was constructed using GENIE, a tool developed at Los Alamos. The paper concludes with a discussion of future research

6234-38, Session 8

Registration, detection, and tracking in 1/6-Hz barscan imagery

A. Mahalanobis, A. V. Forman, J. C. Perez, H. Beydoun, Lockheed Martin Missiles and Fire Control

The primary application for the algorithm presented in this paper is Detection/Tracking of moving objects in wide area search (WAS) barscan imagery. WAS images may span one to five degrees in elevation and 10-360 degrees in azimuth, i.e., they may have thousands of columns of width and less than a thousand columns of height. The imagery may have significant frame-to-frame distortion due to non-constant azimuth scan velocity and other artifacts. The time between frames may be greater than one second (< 1Hz frame rates), and the target motions (in pixels) between frames may be larger than the target projections in pixels. These conditions violate the assumptions of most image-based trackers, which apply variations of Kalman filters and assume imagery updates at 10-60 Hz rates. The algorithm presented in this paper provides the ability to automatically detect and track moving objects in WAS imagery, which is a valuable capability for a military scout on the ground. While to date the algorithm has only been applied to imagery from a stationary platform, it is potentially applicable for motion detection in an “on-the-move” scenario as well. In this paper, we present a Moving Target Detection/Indicator (MTI) algorithm comprised of 3 stages: Registration, Change Detection, and Tracking. We describe each stage and outline its impact on dealing with the challenges introduced with WAS images (sampling artifacts, long revisit time...). Then, we present experimental results obtained by exercising this algorithm on Forward Looking Infrared (FLIR) WAS images.

6234-40, Session 8

Recognition of propagating vibrations and invariant features for classification

G. Okopal, P. J. Loughlin, Univ. of Pittsburgh; L. Cohen, Hunter College/CUNY

The vibrations produced by objects, for example by a plate or cylinder insonified by a sonar wave, exhibit characteristics unique to the particular structure, which can be used to distinguish among different objects. The situation is complicated, however, by many factors, a particularly important one being propagation through media. As a vibration propagates, its characteristics can change simply due to the propagation channel; for example, in a dispersive channel, the duration of the vibration will increase with propagation distance. These channel effects are clearly detrimental to automatic recognition because they do not represent the object of interest and they increase the variability of the measured responses, especially if measurements are obtained from targets at different locations. Our principal aim is to identify characteristics of propagating vibrations and waves that may be used as features for classification. We discuss various moment-like features of a propagating vibration. In the first set of moments, namely temporal moments such as mean and duration at a given location, we give explicit formulations that quantify the effects of dispersion. Accordingly, one can then compensate for the effects of dispersion on these moments. We then consider another new class of moments, which are invariant to dispersion and hence may be useful as features for dispersive propagation. We present results from classifications experiments comparing these invariant features to related non-invariant features.

6234-41, Session 8

Recognition and classification of nonstationary background noises

L. Cohen, Hunter College/CUNY; L. Galleani, Politecnico di Torino (Italy)

Background noises can be crucial factors in target recognition and under certain circumstances can be as important in understanding the physical situation as much as deterministic signals. We have developed a new method to study nonstationary noises. In our approach we take the governing time equations and convert them into governing time-frequency phase space equations. This results in an immense simplification. With this method we can study nonstationary noises and also the transient part of noises that have been turned on and evolve into stationarity. A number of examples

will be given and methods to classify and recognize various noises will be discussed.

6234-42, Session 8

Evolutionary approach to human body registration

I. V. Maslov, The Graduate Ctr./CUNY; I. Gertner, City College/CUNY

Preliminary results are discussed on human body registration through unsupervised learning, in the form of a Hybrid evolutionary algorithm (HEA). Registration problem is formulated as the optimization problem of finding a proper mapping between object(s) in a multi-object scene and an image of human body. The paper proposes an extension of the HEA-based method of the 2-dimensional image mapping to the elastic 3-dimensional case. A set of image transformations is sought such that each transformation is applied to a different section of the image subject to mapping. The sought image transformation becomes a piece-wise approximation of the actual elastic transformation of the human body. The 2-D optimization problem of finding a parameter vector minimizing the difference between the images turns into a multi-objective optimization problem of finding a set of feasible parameter vectors that minimize the differences between the sections of the compared images. The search for a proper set of image transformations is conducted in a feature space formed by image local response, as opposed to a pixel-wise comparison of the actual images in the 2-D case. Using image response allows to reduce the computational cost of the search by applying thresholding techniques and a piece-wise approximation of the response matrix. The difference between the images is evaluated in the response space by minimizing the distance between the two-dimensional central moments of the image responses.

6234-43, Session 8

Distributed sensor networks data fusion schemes for detection of suspicious behaviors

A. H. Shirkhodaie, H. Rababaah V, E. Kusco, Tennessee State Univ.

Wireless sensor network offers opportunity to perform detection, recognition, classification, and tracking of multi-targets in complex environments. In many battlefield and urban terrain environments, for instance, such sensor network system can be employed to perform automatic surveillance operations using imaging and other sensing devices. The widespread use of sensors such as imaging devices has made them essential sensors for non-invasive surveillance of battlefields and urban terrains where environment access areas are provisional restricted and additional preventive measures are required to protect the environment. For such applications, a network of multi-modal sensors can be deployed to distinguish suspicious activities from normal activities and monitor infringement to restricted areas automatically. The distribution diversity of sensor networks provides data fusion of multi-sensory devices both temporally and spatially. By effective data fusion, it would be possible substantiate the suspicious acts from anomalous behaviors and communicate act of aggression to the security authorities. However, suspicious act is usually rare, and it can be extremely tedious for people to monitor for the atypical occurrences. It is therefore, desirable to automate the detection process. In this paper, a mathematical modeling approach is presented for differentiation of suspicious acts from anomalous behaviors, and different methods for characterization of deceptive acts are discussed. Furthermore, a strategy based on Bayesian framework for statistical, multi-modal sensor fusion is presented. The framework is based on a joint likelihood function with a marked Poisson prior. The Bayesian framework is demonstrated with a metropolis-hasting algorithm that generates inferences. The framework is demonstrated using experiments involving simulated suspicious acts in urban terrain environments.

6234-45, Session 8

Information-theoretic bounds on target recognition performance from laser radar data

J. A. Dixon, A. D. Lanterman, Georgia Institute of Technology

Laser radar systems offer rich data sets for automatic target recognition. ATR algorithm development for laser radar has focused on achieving real-time performance with current hardware. In comparison, little work has been done on understanding how much information can be squeezed from the data, independent of any particular algorithm. To help fill this gap, will present information-theoretic bounds based on statistical models for laser radar data. For raw imagery, we employ models based on the underlying physics of the detector. For assembled “point clouds,” whose statistics are a complex interaction of the underlying sensor characteristics and the jigsaw puzzle algorithms used to assemble multiple views, we consider a Poisson point process model chosen for its analytical tractability.

Most ATR algorithms for laser radar data are designed to be “invariant” with respect to position and orientation. Our information-theoretic bounds illustrate that even algorithms that do not explicitly involve the estimation of such nuisance parameters are still effected by them.

Conference 6235: Signal Processing, Sensor Fusion, and Target Recognition XV

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6235-02, Session 1

Observable operator model-based joint target tracking and classification

S. Sutharsan, A. Sinha, T. Kirubarajan, McMaster Univ. (Canada)

In this paper, Observable Operator Model (OOM) based joint target tracking and classification technique is considered. The OOM approach, which has been proposed as a better alternative to the Hidden Markov Model (HMM), is used to model the stochastic process of target classification. These OOMs afford both mathematical simplicity and algorithmic efficiency compared to HMM. Conventional classification techniques use only the feature information from target signatures. The proposed OOM based classification technique incorporates the target-to-sensor orientation together with a sequence of feature information extracted from the multi-aspect scattering data. The target-to-sensor orientation evolves over the time and the target aspect is important in determining the target classes. The target aspect state sequence is modeled using OOM to estimate unknown target orientation. This algorithm exploits the inter-dependency of target state and the target class, which improves both the state estimates and classification of each target.

A two dimensional example demonstrates the merits of the proposed OOM based classification algorithm and the results are compared with those obtained via HMM based classification.

6235-03, Session 1

Impact time and point prediction: an analysis of the capabilities of a neural extended Kalman filter

S. C. Stubberud, The Boeing Co.; K. A. Kramer, Univ. of San Diego

Part of target tracking is the use of existing information to predict future behavior. Often, this part of the tracking algorithm is used for data association and the update step of the fusion process as well as more recently to guide weapons to the target. Another application is to estimate the point of impact of enemy munitions such as mortar shells. The determination of the actual threat posed by enemy position permits prioritization of targets for response and can limit the need to expose friendly units until a better engagement opportunity arises.

The flight trajectory of ballistic ordinance, while theoretically understood, can be affected by a number of unknown factors, such as air turbulence and drag. To accurately predict the projectile's flight path, an adaptive Kalman filter approach is proposed to both track and predict the target trajectory. The Kalman filter uses a neural network as an on-line function approximator to improve the target motion model of the target tracking. The neural network is trained in conjunction with the tracking algorithm. Both the track states and the neural network weight use the same residual information. The neural network model is added to the motion model and provides an improved track prediction of a mortar impact time and its location. Analysis of the approach's performance is compared to varying tracking systems with different levels of target motion accuracy. Two a priori motion models for the neural approach are applied: a straight-line motion model and a basic ballistic trajectory. The results show the ability of the technique to provide accurate target predictions with limited a priori information.

6235-04, Session 1

A nonlinear filtering and predication (NFP) method for maneuvering target tracking

H. Chen, K. C. Chang, George Mason Univ.

A new non-linear filtering and predication (NFP) algorithm with input estimation is proposed for maneuvering target tracking. In the proposed method, the acceleration level is determined by a decision process, where a least squares (LS) estimator plays a major role to detect target maneuvering within a sliding window. In this paper, we first illustrate that the optimal solution to minimize the mean squared error (MSE) must consider a trade-off between the bias and error variance. For the application of target tracking, we then derive the MSE of target positions in a close form by using orthogonal space decompositions. Then we discuss the NFP estimator, and evaluate how well the approach potentially works in the case of given system parameters. Comparing with the traditional unbiased minimum variance filter (UMVF), Kalman filter, and interactive multiple model (IMM) algorithms, numerical results show that the newly proposed NFP method performs comparable or better than the others in all the scenarios with less computational requirements.

6235-05, Session 1

Radar signals dismount imaging for tracking during urban operations

E. P. Blasch, U. K. Majumder, M. J. Minardi, Air Force Research Lab.

It is critical in urban environments to not only track cars and tanks; but also the individuals. Tracking dismounts can be done using conventional Electro-Optical (full color) or Infrared (thermal) cameras. However, EO/IR systems are subject to weather and line-of-sight conditions (i.e. person blocked by cloud) as well are degraded for long ranges. In this study, we pursue the use of radar images for dismount tracking. Radio Frequency (RF) tracking of dismounts is a relatively new concept because the data has not been available. By forming a data set based on the POSER program, and post-processing the data for realism, we are interested in exploring the possibility of RF dismount tracking. In this paper, we (1) explore the generation of RF dismount data, (2) apply tracking algorithms to locate the moving target, and (3) assess the performance using the Cramer-Rao Lower Bound (CRLB).

6235-06, Session 1

Multiple target tracking with a steerable airborne video sensor

P. O. Arambel, M. Antone, BAE Systems Advanced Information Technologies

Tracking multiple surface targets with a single steerable airborne video sensor is accomplished by several interrelated functions: (i) image registration for camera motion compensation and accurate image-to-ground mapping, (ii) video processing for object detection and feature extraction, (iii) target tracking for detection association and track creation and maintenance, and (iv) sensor resource management for the generation of sensor steering commands. The first function is often overlooked, but has a significant impact in the performance of the overall system. A rudimentary registration can be achieved by using the platform location and attitude as well as the sensor orientation and field of view information, but the accuracy of this registration is typically poor due to GPS and inertial navigation system errors, particularly in small unmanned aerial vehicles with cost and hardware limitations. Successful image-processing-based

registration of successive frames enables the use of multiple frame video processing for improved object detection and provides stable image-to-ground mapping for improved data association by the tracker. In systems with a steerable sensor that slews back and forth to track more than one target simultaneously, the image registration module creates and maintains multiple mosaics corresponding to the different tracking areas. In this paper we discuss the image registration module and its interaction with the other modules of the system.

6235-07, Session 2

Automatic motion model estimation and target detection in video sequences with arbitrary camera motion

L. Ma, Arizona State Univ.; G. P. Abousleman, General Dynamics C4 Systems; J. Si, Arizona State Univ.

This paper presents a global motion model estimation and target detection algorithm for video target tracking applications with moving cameras. The proposed algorithm analyzes the foreground-background structure of a video frame and detects objects that have independent motion. Each video frame is first segmented into regions where image intensity and motion fields are homogeneous. Global motion model fitting is then performed using linear regression of the motion vectors through iterations of region searching. Since the motion field is calculated using non-parametric estimation, the proposed method is much more efficient than direct estimation of the motion parameters. Additionally, the proposed method can detect outliers that contain independent moving targets. The algorithm is much more computationally efficient than parametric motion estimation, and is also much more robust as compared to background-compensation-based detection. The performance of the algorithm is demonstrated on a variety of video sequences, where the targets are reliably detected within the moving background.

6235-08, Session 2

Localized particle subset tracking for real-time video applications

L. Ma, Arizona State Univ.; G. P. Abousleman, General Dynamics C4 Systems; J. Si, Arizona State Univ.

In this paper, a localized particle subset method is proposed to solve target-tracking problems in a Bayesian inference framework. Rather than use particles to estimate the posterior probability density function (pdf) of the targets, a subset of the particles is used. This subset of particles is selected by estimating the motion of the targets. The weights of the particles are updated by the 3-D Hausdorff distances between the target appearance model and the samples. The proposed method is highly efficient in particle utilization, which results in a significant reduction of the samples utilized in the prediction and update processes. It also alleviates the sample degeneracy and impoverishment in the sampling process. Experiments demonstrate that the computational complexity for our proposed localized particle subset tracker is a fraction of that of conventional Sequential Importance Sampling (SIS) trackers, while the tracking performance is comparable to SIS particle filter trackers.

6235-09, Session 2

Autonomous search, classification, and tracking by multiple cooperative UAVs

A. Sinha, T. Kirubarajan, McMaster Univ. (Canada); Y. Bar-Shalom, Univ. of Connecticut

In this paper we propose a cooperative control algorithm for a group of UAVs carrying out surveillance — search, classification and tracking — over a large region which includes a number of targets. The goal is to track and classify the detected targets as well as search for the undetected ones. The UAVs are assumed to be equipped with Ground Moving Target Indicator (GMTI) radars, which measure the locations of moving ground targets as well as their radial velocities (Doppler). Also, another sensor is mounted on each UAV that can extract attribute information yielding classification. The surveillance region is divided into a number of sectors and it is assumed that the GMTI sensor on each UAV scans a fixed number of such sectors in each period of its operation. The attribute extractor can scan at most one target in each period of time. In this paper, a decentralized cooperative control algorithm is proposed, according to which each UAVs transmits the current scan information (both kinematic and class information) and detection information (including "negative information") to a number of closest UAVs. Each UAV makes its scan decision and path decision separately, based on information based objective functions, which incorporate target state information as well as target detection probability and survival probability due to possible hostile fire by targets and collision with other UAVs. The proposed algorithm requires limited communication and modest computation and it can handle failure in communication and loss of UAVs.

6235-10, Session 2

An entropy-based approach to wide-area surveillance

G. E. Collins, M. R. Meloon, K. J. Sullivan, Toyon Research Corp.

The use of measures from information theory to evaluate the expected utility of a set of candidate actions is a popular method for performing sensor resource management. Shannon entropy is a standard metric for information. Past researchers have shown \cite{kastella97}, \cite{hintz96}, \cite{hintz97}, \cite{shannon}, \cite{xiong}, etc., that the discrete entropy formula can measure the quality of identification information on a target, while the continuous entropy formula can measure kinematic state information of a target. In both cases, choosing controls to minimize an objective function proportional to entropy will improve one's information about the target. However, minimizing entropy does not naturally promote detection of new targets or "wide area surveillance" (WAS). This paper outlines a way to use Shannon entropy to motivate sensors to track (partially) known targets and survey the search space to discover new targets simultaneously. Results from the algorithmic implementation of this method show WAS being favored when most targets in the search space are unknown, and tracking being favored when most targets are in track. The tradeoff between these two competing objectives is adjusted by the objective function automatically and dynamically.

6235-11, Session 2

A sparse sampling planner for sensor resource management

M. Rudary, Univ. of Michigan; D. Khosla, HRL Labs., LLC; A. Dow, Univ. of California/Los Angeles; B. J. Blyth, Raytheon Co.

The goal of sensor resource management (SRM) is to allocate resources appropriately in order to gain as much information as possible about a system. We introduce a non-myopic planning algorithm, SparsePlan, that uses sparse sampling to estimate the value of resource assignments. Sparse sampling is related to Monte Carlo simulation. In the SRM problem we consider, our network of sensors observes a set of tracks; each sensor can be set to operate in one of several modes and/or viewing geometries. Each mode incurs a different cost and provides different information about the tracks. Each track has a kinematic state and is of a certain class; the sensors can observe either or both of these, depending on their mode of operation. The goal in this problem is to maximize the overall rate of information gain, i.e. rate of improvement in kinematic tracking and classification accuracy of all tracks in the Area of Interest. The rate is defined by several metrics with the cost of the sensor mode being the primary factor. We compare SparsePlan's performance on several tracking and target identification problems to that of other algorithms. We also extend the planning algorithms to distributed frameworks and show some preliminary performance results.

6235-12, Session 2

Instantiation of dynamic goals based on situation information in sensor management systems

M. S. Henning, K. J. Hintz, George Mason Univ.

Previous papers introduced an extension to the concept of goal lattices (GL) that allows a sensor manager to instantiate dynamic goals within an existing goal lattice to account for changes in the operating environment and operational modes. The goal lattice construct provides a means of determining the relative value of a particular sensor action (such as search, track, and ID functions) with respect to the mission goals. A sensor manager instantiates dynamic goals from a set of predefined classes of goals along with their interconnections into the existing static mission goal lattice. Given these mechanisms, a sensor manager needs a method of determining which dynamic goal to instantiate given the situational environment (i.e. whether to track or ID given a detection). This paper introduces the concept of situation information and presents a method for measuring that information and using it to select the next dynamic goal (information request) to launch in response to the search, track, or ID information obtained from completion of the previous dynamic goal.

6235-13, Session 3

Resource manager for autonomous control of a coordinated team of UAVs making meteorological measurements

J. F. Smith III, Naval Research Lab.

A recently developed fuzzy logic resource allocation algorithm that enables a collection of unmanned air vehicles (UAVs) to automatically cooperate as they make meteorological measurements will be discussed. The goal of the UAVs' coordinated effort is to measure the atmospheric index of refraction. Once in flight no human intervention is required. A fuzzy planning algorithm determines the optimal trajectory, sampling rate and pattern for the UAVs and an interferometer platform while taking into account risk, reliability, priority for sampling in certain regions, fuel limitations, mission cost, and related uncertainties. The real-time fuzzy resource manager (RM) running on each UAV will give the UAV limited autonomy allowing it to change course immediately without consulting with any commander, request other UAVs to help it, alter its sampling pattern and rate when observing interesting phenomena, or to terminate the mission and return to base. The RM allows three types of cooperation between UAVs. Significant simulation results will show the RM's effectiveness in producing cooperative behavior. The index of refraction data base will be shown to be significantly improved by incorporation of measurements made by the UAVs. Examples showing the effectiveness of cooperating UAVs over non-cooperative behavior will be provided. The underlying optimization procedures including the fuzzy logic based cost functions and the fuzzy logic priority schemes for cooperation will be discussed. Finally, through a process known as matched field processing the improved index of refraction values will be used to provide high quality estimates of the positions of electromagnetic sources.

6235-14, Session 3

Farsighted sensor management for feature-aided tracking

A. Nedich, M. K. Schneider, X. Shen, BAE Systems Advanced Information Technologies; D. Lea, Air Force Research Lab.

We consider the sensor management problem arising in air-to-ground tracking of moving targets. The sensing-tracking system includes a multi-mode sensor and a feature-aided tracker. The sensor management problem is to determine where and what kind of data to collect on targets in time so as to optimize the utility of the collected data. Finding the optimal data collection is a hard combinatorial problem due to many factors, including the large number of possible sensor actions and the complexity of the dynamics. The complexity of the dynamics is due in part to the degradation of the fused data in the absence of new data as well as the cross-dependency of various uncertainties that are present in the sensing-tracking system. For example, the uncertainty in the sensor detection process is affected by the uncertainties in the target location estimates. We formulate the sensor management problem as a stochastic dynamic program. In this formulation, we expose a special structure of the problem resulting from target dynamics being independent, and we discuss how to exploit this structure in solution strategies. We illustrate this on a problem of managing a single sensor having two modes, where one of the modes provides feature-related data.

6235-15, Session 3

A rollout algorithm to coordinate multiple sensor resources to track and discriminate targets

M. K. Schneider, C. Chong, BAE Systems Advanced Information Technologies

This paper presents a novel, scalable optimization approach to coordinating multiple sensor resources to track and discriminate targets. The sensor resource management problem is one of allocating sensors on a time scale of seconds in a closed loop that includes a target tracker and classifier. Allocations specify how the sensors should be pointed and the modes in which they should operate. The objective is to optimize the collection of data to meet tracking and discrimination goals. Quality of the data collected will be different for different allocations, in part, because the quality of the data collected on a target by a sensor depends on the relative geometry between the sensor and target. The optimization of the data collection is to be done subject to constraints on sensors' fields of view as well as time required to slew a sensor into position, if it has mechanical gimbals, and to collect data in the selected mode. The problem is challenging because of the large number of possible sensor allocations as well as the complex dynamics. For this problem, we have developed a novel, approximate dynamic programming algorithm, a type of rollout algorithm, to optimize sensor allocations to coordinate multiple sensor resources. The approach is scalable to realistically sized problems. The paper overviews the approach and results from applying the algorithm.

6235-16, Session 3

Sensor management for multiple target tracking with heterogeneous sensor models

J. L. Williams, J. W. Fisher III, A. S. Willsky, Massachusetts Institute of Technology

Modern sensors are able to rapidly change mode of operation and steer between physically separated objects. While control of such sensors over a rolling planning horizon can be formulated as a dynamic program, the optimal solution is inevitably intractable. In this paper, we consider the control problem under a restricted family of policies and show that the essential sensor control trade-offs are still captured. The advantage of this approach is that one can obtain the optimal policy within the restricted class in a tractable fashion, in this case by using the auction algorithm. The approach is well-suited for problems in which a single sensor (or group of sensors) is being used to track many targets using a heterogeneous sensor model, i.e., where the quality of observations varies with object state, such as due to obscuration. Our algorithm efficiently weighs the rewards achievable by observing each target at each time to find the best sensor plan within the restricted set. We extend this approach using a roll-out algorithm, to handle additional cases such as when observations take different amounts of time to complete. We explore the performance of the algorithm through a variety of simulated scenarios, demonstrating the effectiveness of the method across a broad range of operating conditions.

6235-17, Session 4

Real-time 3D ladar imaging

P. L. Cho, H. Anderson, R. E. Hatch, P. Ramaswami, MIT Lincoln Lab.

Recent advances in ladar imaging technology have opened many new possibilities for intelligence gathering and information visualization. Ongoing programs at Lincoln Laboratory have demonstrated an impressive potential of ladar sensing for synoptic urban surveillance, dense foliage penetration and Improvised Explosive Device detection. In future conflicts, detailed 3D images of cities, jungles and deserts will prove invaluable to the warfighter, particularly if they are delivered in a timely fashion. In this talk, we report upon a prototype image-processing system which generates, displays and analyzes ladar data in real-time.

We first discuss the real-time system's experimental setup. Its raw data stream comes from a ladar previously developed under the DARPA Jigsaw program. Jigsaw's short pulse transmitter coupled with its Avalance Photo-Diode (APD) array receiver yield high resolution angle-angle-range information. We next present a suite of novel algorithms that transform raw ladar data into cleaned 3D images. These image processing techniques include signal amplification and noise reduction, ground plane identification and APD response function deconvolution. Our algorithms also discriminate static objects and dynamic targets in a scene. This automatic classification represents a nontrivial degree of machine intelligence, for the Jigsaw illumination pattern introduces complex temporal dependence into the data that is independent of genuine target motion.

Our algorithms run at approximately 10 x real-time on a 3 GHz processor. In order to achieve an order of magnitude speed-up, we have parallelized our C++ codes on a Linux cluster. We demonstrate how inter-process communication software coupled with Blade hardware result in a compact adjunct to the Jigsaw ladar which generates 3D images in real-time.

Finally, we close by mentioning several interesting directions for future work. They include automatic tracking of mobile targets, exterior reconnaissance of building interiors and ladar/video imagery fusion.

6235-18, Session 4

START for evaluation of target detection and tracking

S. K. Ralph, M. R. Stevens, Charles River Analytics, Inc.; J. M. Irvine, Science Applications International Corp.; J. Marvel, M. S. Snorasson, Charles River Analytics, Inc.; A. C. Rice, Air Force Research Lab.

A major challenge for ATR evaluation is developing an accurate image truth that can be compared to an ATR algo-rithm's decisions to assess performance. We have developed a semi-automated video truthing application, called START, that greatly improves the productivity of an operator truthing video sequences. The user, after previewing the video and selecting salient frames (called "keyframes"), manually truths the keyframes. Various truthing strategies are then be applied to compute the image truth for the remaining frames. The application uses a set of diagnostic measures to manage the user's attention, flagging portions in the video for which the computed truth needs review. This changes the role of the operator from raw data entry, to that of expert appraiser supervising the quality of the image truth. We provide a spectrum of truthing tools, including fully-automatic feature tracking, interpolation, and completely manual methods. The role of the user in the truthing shifts from a manual-labor per frame truther, to a more supervisory role in which the choice of the truthing algorithm is chosen.

We have implemented a number of graphical displays summarizing the video truthing at various timescales. Addition-ally, we can view the track information, showing only the lifespan information of the entities involved. A combination of these displays allows the user to manage their resources more effectively.

We have conducted two studies that have shown the utility of START: one focusing on the accuracy of the automated truthing process, and the other focusing on usability issues of the application by a set of expert users.

6235-19, Session 4

Seeker-sensor fusion approaches for precision guided munitions

W. C. Snyder, BAE Systems Advanced Information Technologies

Reductions in ladar seeker cost, size, and weight have made it a viable technology for target search and terminal guidance to enhance the time critical targeting capability of small, precision guided munitions (PGMs) such as PLOCAAS. These munitions typically have GPS/INS guidance, but by adding a ladar seeker we can improve their capability to engage targets whose coordinates are not known exactly, or that have moved. At the same time, stand-off, reconnaissance SAR for targeting and weapon tasking will be available on an ongoing basis in many scenarios where these ladar PGMs would be deployed. So in addition to the traditional SAR uses, we present an approach to exploit the valuable and timely scene information from the SAR sensor to enhance the LADAR seeker mission (thus seeker-sensor fusion). The question is how to fuse these disparate sources of data to maximize mission effectiveness. We vet a number of approaches to SAR-LADAR fusion including target transfer, evidence fusion, and pre-ATR cueing and we present our progress in implementing and evaluating the more promising ones.

6235-20, Session 4

Information management and target detection for multisensor airborne platforms

K. J. Jaeger, M. Hebel, K. Bers, W. Armbruster, FGAN-FOM (Germany)

Future military helicopters will be equipped with multiple information sources for self-protection and reconnaissance, e.g. imaging IR, laser radar and GPS. In addition, knowledge bases like maps, aerial images, geographical information (GIS) and other previously acquired data can be used for the interpretation of the current scenario. The results of data fusion and information management have to be presented to the pilot in an appropriate way to support the mission.

This paper describes concepts and results of our work on IR and laser data fusion. A multi-sensor suite (infrared FPA, scanning laser radar) together with an inertial measurement unit has been attached to a Bell UH1-D helicopter. The gyro-based IMU provides navigation data that can be combined with GPS information to achieve absolute accuracy of the gathered multi-sensor data (IR imagery, laser range data). The laser scanner itself is an 1.5 μm erbium fiber system, derived from the EADS HELLAS family, that covers a field-of-view of 14.4 degrees in horizontal and vertical direction with a resolution of 128x128 pixels and a scan rate of about 4 Hz. The infrared images are taken with an AIM 8-10 μm FPA sensor (640x480 pixels) and a slightly wider field-of-view which overlaps that of the laser. For further improvement, fusion with collateral information (laser elevation data, aerial images) is used for change detection and definition of regions of interest with respect to the stored and continuously updated database.

Results are shown by the analysis of an exemplary data set, showing a scenario with a group of vehicles seen by a forward moving sensor platform. Two moving vehicles are detected automatically in both IR and laser channel, and the results are combined to achieve improved visualization for the pilot.

6235-21, Session 5

A theory of PHD filters of higher order in target number

R. P. Mahler, Lockheed Martin Corp.

The probability hypothesis (PHD) filter is a first-order approximation of the multitarget Bayes filter. Instead of recursively propagating the multitarget posterior density function, it propagates its first-order

multitarget moment. This moment, the PHD, is a non-probability density on single-target state space. Since the integral of the PHD is the expected number of targets, the PHD filter also inherently propagates the first moment of the target-number probability distribution (TNPD). During a presentation at the 2005 International Conference on Information Fusion, Prof. Peter Willett suggested that the PHD filter's performance could be improved if one could devise a version that also propagated a second-order moment of the TNPD. This paper establishes a theoretical foundation for such filters. We introduce a generalization of the PHD filter, the "cardinalized PHD" (CPHD) filter, which propagates both the PHD and the TNPD. Using explicitly specified multitarget statistical motion and measurement models, we show that it is possible to derive closed-form time-update and data-update equations for the CPHD filter. The latter is more general than the usual PHD time-update formula in that composite-Poisson (and not just Poisson) false alarm models are allowed. Since the data-update equation for the TNPD is combinatorially complex, additional approximations may be necessary for real-time application. We discuss some possibilities for these.

6235-22, Session 5

A distributed implementation of a sequential Monte Carlo probability hypothesis density filter for sensor networks

K. Punithakumar, T. Kirubarajan, A. Sinha, McMaster Univ. (Canada)

This paper presents a Sequential Monte Carlo (SMC) Probability Hypothesis Density (PHD) algorithm for decentralized state estimation from multiple platforms. The proposed algorithm addresses the problem of communicating and fusing track information from a set of multiple sensing platforms detecting and tracking multiple targets in the surveillance region. Each platform receives multiple, noisy measurements about the time-varying states that describe the targets. The target state involves potentially nonlinear target dynamics described by Markovian state-space model, nonlinear measurements, and non-Gaussian process and measurement noises. Each sensing platform reports measurements to a node in the network, which performs sequential estimation of the current system state using the probability hypothesis density (PHD) filter that propagates only the first-order statistical moment of the full target posterior of the multi-target state. A sequential Monte Carlo method is used to implement the filter. The crucial consideration is what information needs to be transmitted over the network in order to perform online estimation of the current states of the targets, whilst attempting to minimize communication overhead. Simulation results demonstrate the efficiency of the proposed algorithm for a set of bearing only sensors.

6235-23, Session 5

Advancements in situation assessment sensor management

A. I. El-Fallah, A. Zatezalo, Scientific Systems Co., Inc.; R. P. Mahler, Lockheed Martin Corp.; R. K. Mehra, Scientific Systems Co., Inc.; M. G. Alford, Air Force Research Lab.

In last year's conference we demonstrated new results using a foundational, joint control-theoretic

approach to situation assessment (SA) and SA sensor management that is based on a "dynamic situational significance map", the maximization of the expected number of targets of tactical interest, and approximate multitarget filters (specifically, first-order multitarget moment filters and multi-hypothesis correlator (MHC) engines). This year we report on the following new developments and extensions: (1) a tactical significance function based on the fusion of different ambiguous attributes from several different sources; (2) a Bayes' belief network formulation for multi-target tracking and information fusion; and (3) a recursive closed form expression for the posterior expected number of targets of interests (PENTIs) for ANY number of sources. Result of testing this sensor management algorithm with significance maps defined in terms of targets/attributes interrelationships using simplified battlefield situations will demonstrate that these new advancements allow for a better SA, and a more efficient SA sensor management.

6235-24, Session 5

Regularized multitarget particle filter for sensor management

A. I. El-Fallah, A. Zatezalo, Scientific Systems Co., Inc.; R. P. Mahler, Lockheed Martin Corp.; R. K. Mehra, Scientific Systems Co., Inc.; M. G. Alford, Air Force Research Lab.

Sensor management in support of Level 1 data fusion (multisensor integration), or Level 2 data fusion (situation assessment) requires a computationally tractable multitarget filter.

The theoretically optimal approach to this multi-target filtering is a suitable generalization of the recursive Bayes nonlinear filter. However, this optimal filter is intractable and computationally challenging that it must usually be approximated.

We report on the approximation of a multi-target non-linear filtering for Sensor Management that is based on the particle filter implementation of Stein-Winter probability hypothesis densities (PHDs). Our main focus is on the operational utility of the implementation, and its computational efficiency and robustness for sensor management applications. We present a multitarget Particle Filter (PF) implementation of the PHD that include clustering, regularization, and computational efficiency. We present some open problems, and suggest future developments. Sensor management demonstrations using a simulated multi-target scenario are presented.

6235-25, Session 5

Bayes-invariant transformations of uncertainty representations

R. P. Mahler, Lockheed Martin Corp.

Much effort has been expended on devising conversions of one uncertainty representation scheme to another-fuzzy to probabilistic, Dempster-Shafer to probabilistic, to fuzzy, etc. Such efforts have been hindered by the fact that uncertainty representation formalisms vary considerably in the degree of complexity of information which they encode. For example, 2^M-1 numbers are required to specify a Dempster-Shafer basic mass assignment (b.m.a.) on a space with M elements; whereas only M-1 numbers are required to specify a probability distribution on the same space. Consequently, any conversion of b.m.a.'s to probability distributions will result in a huge loss of information. In addition, conversion from one uncertainty representation formalism to another should be consistent with the data fusion methodologies intrinsic to these formalisms. For example, fusion of b.m.a.'s is commonly accomplished using Dempster's combination. Fusion of fuzzy membership functions, on the other hand, is usually accomplished using fuzzy conjunction. For b.m.a.'s to be consistently converted to fuzzy membership functions, Dempster's combination should be transformed into fuzzy conjunction in some sense. The path out of such quandaries is to realize that no matter how complex or disparate various kinds of information might be, ultimately they must be reduced to summary information: state estimates and covariances. In a Bayesian formulation, estimates are derived from posterior probability distributions. Thus the conversion problem can be restated as: What conversions between uncertainty representations leave posterior distributions unchanged? In this paper we answer this question by identifying Bayes-invariant conversions between various uncertainty representation systems.

6235-26, Session 5

Differential geometry measures of nonlinearity

M. K. Mallick, Toyon Research Corp.; B. F. La Scala, The Univ. of Melbourne (Australia); M. S. Arulampalam, Defence Science and Technology Organisation (Australia)

Cartesian coordinates and modified polar coordinates are commonly used to represent the state vector in the bearing-only tracking problem. A widely studied bearing-only problem considers a nearly constant velocity motion (NCVM) of the target in 2D with a maneuvering ownship. If the Cartesian coordinates are used to represent the state vector, then the dynamic model is linear and the measurement model is nonlinear. On the other hand, if the modified polar coordinates are used, the dynamic model is nonlinear and the measurement model is linear. In both cases, the filtering problem is nonlinear in nature. A great deal of attention has been focused on this problem due to the difficulty posed by the so-called high degree of nonlinearity (DoN). In a previous work, we calculated two differential geometry based measures of nonlinearity, the parameter-effects curvature and intrinsic curvature. The Cartesian coordinates were used to represent the state vector.

In this paper, we present calculation of the parameter-effects curvature and intrinsic curvature measures of nonlinearity for the bearing-only tracking problem using the modified polar coordinates representation of the state vector. We present numerical results using simulated data for the NCVM of a target in 2D with bearing-only measurements where the ownship uses a higher order motion than the target to achieve observability. We compare the curvature measures of nonlinearity for the Cartesian coordinates and modified polar coordinates representations of the state vector.

6235-27, Session 5

Improved kinematic state estimates through joint tracking and classification

C. S. Agate, R. M. Wilkerson, Toyon Research Corp.

Joint tracking and classification (JTC) is traditionally a difficult problem since it requires the joint estimation of continuous random variables and a discrete random variable. The difficulty lies in the representation of such a mixed continuous-discrete probability distribution. Sequential Monte Carlo methods represent the target state probability density function by a collection of points in the state space and, therefore, naturally represent a mixed continuous-discrete density. The potential of jointly estimating the target state and type using kinematic and feature information is the ability to exploit the kinematic information in the feature measurements for improved target state estimates. Since many features are aspect-dependent, there is heading information in the feature measurements which can be exploited for improved target kinematic state estimates. We have extended our previous work on a particle filter for ground targets confined to the road, to a particle filter that tracks vehicles through move-stop-move cycles and on-road-to-off-road transitions using simulated moving target indicator radar and real high-range resolution (HRR) profiles. Results quantify the improvement to

kinematic target state estimates when using features over the case when no features are utilized.

6235-28, Session 5

Multi-environment NLF tracking assessment testbed (MENTAT): an update

R. P. Mahler, Lockheed Martin Corp.; M. Ekhaus, Gibralter Analytics, Inc.; J. A. Spinks, Lockheed Martin Corp.; L. Chen, Scientific Systems Co., Inc.

In applications in which even the best EKFs and MHTs may perform poorly, the single-target and multi-target Bayes nonlinear filters become potentially important. In recent years, new implementation techniques-sequential Monte Carlo (a.k.a. particle-system), Markov chain Monte Carlo, multitarget first-order moment filters, etc.-have emerged that, when hosted on ever more inexpensive, smaller, and powerful computers, make these filters potentially computationally tractable for real-time applications. A methodology for preliminary test and evaluation (PT&E) of the relative strengths and weaknesses of these algorithms is becoming increasingly necessary. The purpose of PT&E is to (1) assess the broad strengths and weaknesses of various algorithms or algorithm types; (2) justify further algorithm development; and (3) provide guidance as to which algorithms are potentially useful for which applications. At last year's conference we described our plans for the development of a PT&E tool, MENTAT. In this paper we report on current progress. Our implementation is MATLAB-based, and harnesses the GUI-building capabilities of the well-known MATLAB tool package, SIMULINK.

6235-29, Session 5

Particle PHD-filter multitarget tracking and data association in sonar data

D. E. Clark, J. M. Bell, Heriot-Watt Univ. (United Kingdom)

The Probability Hypothesis Density (PHD) filter was developed as a sub-optimal method for tracking a time varying number of targets. Sequential Monte Carlo implementations of the PHD-filter have enabled the development of multiple-target tracking algorithms with non-linear and non-Gaussian dynamics which also have the ability to estimate the number of targets in the scene. Asymptotic convergence of the particle filter implementation has been shown and bounds for the mean-square errors have been established which gives theoretical justification for use in tracking applications. Applications of the PHD-filter, based on Particle filtering techniques, have demonstrated that the method can be used for real-time tracking of an unknown number of targets in cluttered environments estimating both the number of targets and their locations, although track continuity has not been maintained. Data association techniques have been developed recently to enable continuity of the individual target tracks and preliminary work has demonstrated their ability on simulated data.

In this paper we demonstrate the PHD-filter to be an effective means of multiple-target tracking with data association in forward-scan sonar data where the number of targets is not known a-priori and in the presence of clutter due to erroneous measurements.

6235-30, Session 6

A system approach to real-world data fusion

F. E. Daum, Raytheon Co.

Crucial issues in real world multi-sensor data fusion include: (1) limited resolution of sensors, (2) residual bias between sensors, (3) data rates, latencies, signal-to-noise ratios, signal-to-clutter ratios, signal-to-interference ratios, and (4) physics of so-called bias. Unfortunately, 99% of the academic and engineering literature on multi-sensor data fusion is focused on algorithmic details or software issues, rather than the crucial issues of resolution, bias and good sensor design. Conspicuous exceptions include the papers of Koch, Levedahl, Chong, Mori, Blom, Musicki and Morelande. It is well known that track fusion is more robust to these real world effects than measurement fusion. But we also know that measurement fusion is theoretically optimal if all real world phenomena are modeled and accounted for in the so-called optimal algorithm. Moreover, we know that modeling such real world effects in suboptimal algorithms can improve system performance substantially; in particular, see papers by Koch, Blom, Musicki and Levedahl. Detailed Monte Carlo simulations by Daum (1986) show that the probability of maintaining track in dense multiple target environments can be improved from 50% to 99% by explicitly modeling unresolved data in the data association algorithm; moreover, the velocity estimation accuracy can be improved (from poor to excellent) using this improved algorithm. The physical phenomena for radar applications that elude academics and most engineers include: range & Doppler resolution, residual tropospheric refraction, residual scan dependent monopulse errors, residual monopulse slope errors, residual radome refraction, etc. Similar lists apply for other types of sensors (e.g., sonar and passive infrared). The algorithmic approach to multi-sensor data fusion is secondary compared with these physical considerations. One can develop a good fusion algorithm using the correct physics with any of the following formalisms: MHT, multi-dimensional assignment, Stone's Bayesian method, Mahler's random set approach, Janossy measures, Kamen's symmetric measurement equations, roll-your-own, and hybrids of the above.

6235-31, Session 6

Algorithm comparison for autonomous distributed fusion

M. E. Liggins II, The MITRE Corp. and George Mason Univ.; K. C. Chang, George Mason Univ.

There has been a great deal of work in developing distributed fusion algorithms applicable to a network centric architecture. Currently there are at least a few approaches including naïve fusion, cross-correlation fusion, information fusion, maximum a posteriori (MAP) fusion, and covariance intersection fusion. The first four techniques are based on a conditional independence assumption between the track-forming nodes. Each of these approaches addresses two fundamental sources of estimate correlation in a distributed network differently - namely, common process noise, and common priors. The fifth assumes a covariance consistency derived by a potential dependency between measurements or estimates, not based on conditional independence but rather has its foundation in the information theory.

Significant performance analyses were provided in the literature for the four conditional independence approaches; however, they were based on a single tracking scenario designed specifically to show how varying process noise and common priors impact each approach. The results are not directly comparable to the covariance intersection approach. This paper will provide a wider range of specifically designed scenarios structured to show performance characteristics for each of the five algorithms and provide a basis for evaluating their strengths and weaknesses.

6235-32, Session 6

Real-time radar data fusion and registration systems for single integrated air picture

A. L. Drozd, ANDRO Computational Solutions; P. K. Varshney, Syracuse Univ.; I. P. Kasperovich, C. E. Carroll, ANDRO Computational Solutions; R. Niu, Syracuse Univ.

This paper will describe the application of distributed, decision-level fusion algorithms using multi-sensor inputs and intelligent systems that can be advantageous to midcourse ballistic target tracking and discrimination problems. The goal of the data fusion process is to operate on a combination of sensor measurements, features, track states, and object type and identification likelihoods to produce a single integrated air picture (SIAP) of the air space to a high degree of accuracy. Technologies that enable this synergistic fusion and interpretation of data at several levels from disparate ground-based missile defense radars and other sensors should enhance system acquisition, tracking and discrimination of threat objects in a cluttered environment and provide enhanced battle space awareness. This paper will discuss the development of intelligent algorithms, software, and hardware necessary to collect, process, and fuse information from multiple radars (either at the same frequency or different frequencies) to form a SIAP based on exploiting feature-aided tracking algorithms. This approach involves the design of an autonomous, expert system based capability to perform real time data fusion of multiresolution radar data for precision detection, discrimination, tracking and identification of midcourse ballistic targets. The DataFusR applies a multisource data fusion simulation methodology to assess the viability of distributed, decision-level tracking/registration/fusion schemes and to intelligently select the best algorithm(s) to achieve the objectives of forming a SIAP.

An additional focus of this paper will be on the validation of benefits provided in dynamic retasking scenarios and demonstrating streamlining of precision target detection and tracking using the DataFusR technologies. The DataFusR approach has potential application to the civil aviation n industry particularly in high traffic terminal areas where Air Traffic Control (ATC) rerouting can occur. Ground based applications are also conceivable such as civil emergency/disaster command centers, weather radar, and complex industrial process monitoring.

6235-33, Session 6

Performance measures for correlated ATR systems with multiple classifiers and multiple labels

C. M. Schubert, S. N. Thorsen, M. E. Oxley, K. W. Bauer, Jr., Air Force Institute of Technology

Significant advances in the performance of ATR systems can be made when fusing individual classification systems into a single combined classification system. Often, these individual systems are dependent, or correlated, with one another. This correlation must be incorporated into the fused classifier system so as not to under- or over-estimate the performance of the new system. Additionally, these systems typically assume that two outcome labels, (for instance, target and non-target) exist. Little is known about the performance of fused classification systems when multiple outcome labels are used. In this paper, we propose a methodology for quantifying the performance of the fused classifier system using multiple labels and adjusting for the correlation between classifier systems. Specifically, a performance measure for a fused classifier system using two classifiers and multiple labels will be developed with emphasis on a three-label system: target, non-target, unknown. The performance measure developed is based on the Receiver Operating Characteristic (ROC) curve. The ROC curve in a two-label system has been well defined and used extensively, in not only ATR applications, but also other engineering and biomedical applications. A ROC manifold is defined and use in order to incorporate the multiple labels. Within this new definition, adjustments are made for the correlation effects between multiple classification systems. Examples of this performance measure for given fusion rules and multiple labels are given.

6235-34, Session 6

Quantifying the robustness of classification systems

S. N. Thorsen, M. E. Oxley, Air Force Institute of Technology

Automatic Target Recognition (ATR) system's performance is quantified using Receiver Operating Characteristic (ROC) curves (or ROC manifolds for more than two labels) and typically the prior probabilities of each labeled-event occurring. In real-world problems, one does not know the prior probabilities and they have to be approximated or guessed, but usually one knows their range or distribution. We derive an objective functional that quantifies the robustness of an ATR system given: (1) a set of prior probabilities, and (2) a distribution of a set of prior probabilities. The ATR system may have two labels or more. We demonstrate the utility of this objective functional with examples, and show how it can be used to determine the optimal ATR system from a family of systems

6235-35, Session 6

Model-based multisource fusion for exploitation, classification, and recognition

W. D. Williams, S. P. McCarty, E. R. Keydel, Science Applications International Corp.

It is generally recognized that multi-source fusion should provide a theoretical benefit to the performance of sensor exploitation algorithms. Often, however, the ability to combine information from multiple sensors is made difficult by the disparate types of data that can be collected by different sensor systems. Even if the collected data is limited to imagery, the registration of pixel data between sensors can be quite complicated. This paper presents a framework for the fusion of multi-source data using a 3-D model as the common reference. The framework supports not only the combination of image data, such as Synthetic Aperture Radar (SAR) and electro-optical (EO), but also various types of non-image data and information that may be derived from sensor measurements. The paper describes a model-based technique to combine spatial image information with other data characteristics by relating the features to specific

structural elements on the 3-D target geometry. An example application is presented using a 3-D model as the means for multi-source fusion.

6235-36, Session 6

Video image fusion process using fuzzy and neuro fuzzy technique

T. J. Meitzler, U.S. Army Tank-automotive and Armaments Command

Image fusion techniques have been used for variety of applications like medical imaging, navigation, homeland security and most importantly in military requirements. Different techniques for image fusion are there and already being extended for real time video fusion. In this paper, a new technique for video image fusion has been given. We exploit both fuzzy and neuro fuzzy techniques for image fusion. This approach has already been implemented for multi image fusion for different applications. In the fuzzy approach, pixel of one image is fused with the corresponding pixel value of other image. Fusion is based on the associated rules and membership grades of the frames. In the neuro fuzzy approach, system is trained by the matrix having values from 0-255 for one to one correspondence to the output column. After the training, system can be used for fusion of two or more image frames pixel wise. For the video image fusion, frames are extracted from the two incoming videos and registered. Size and warping of the frames are checked for the suitability of the fusion process. After frame wise fusion using fuzzy or neuro fuzzy approach, they are sequenced back for video display. Various other issues like real time implementation, noise effect, warp function, adaptation required according to application and image alignments have been discussed. We hope that algorithm developed for video image fusion process in this paper will prove to be very effective for real time sensor fusion process.

6235-37, Session 6

Optimization of multisource information fusion for resource management with remote sensing imagery: an aggregate regularization method with neural network implementation

Y. V. Shkvarko IV, Ctr. de Investigación y de Estudios Avanzados (Mexico); S. Butenko, Texas A&M Univ.

We address a new approach to the problem of improvement of the quality of multi-grade spatial-spectral images provided by several sensing systems as required for environmental resource management with the use of multisource remote sensing data. The problem of multi-spectral reconstructive imaging with multisource information fusion is stated and treated as an aggregated ill-conditioned inverse problem of reconstruction of a high-resolution image from the data provided by several sensor systems that employ the same or different image formation methods. The proposed fusion-optimization technique aggregates the experiment design regularization paradigm with neural-network-based implementation of the multisource information fusion method. The maximum entropy requirement and projection regularization constraints are posed as prior knowledge for fused reconstruction and the experiment-design regularization methodology is applied to perform the optimization of multisource information fusion. Computationally, the reconstruction and fusion are accomplished via minimization of the energy function of the proposed modified multistate Hopfield-type neural network that integrates the model parameters of all systems incorporating a priori information, aggregate multisource measurements and calibration data. The developed theory proves that the designed maximum entropy neural network (MENN) is able to solve the multisource fusion tasks without substantial complication of its computational structure independent on the number of systems to be fused. For each particular case, only the proper adjustment of the MENN's parameters (i.e. interconnection strengths and bias inputs) should be accomplished. Simulation examples are presented to illustrate the good overall performance of the fused reconstruction achieved with the developed MENN algorithm applied to the real-world multi-spectral environmental imagery.

6235-38, Session 7

Issues and challenges of knowledge representation and reasoning methods in situation assessment (Level 2 Fusion)

E. P. Blasch, Air Force Research Lab.; D. Corkill, Univ. of Massachusetts/Amherst; S. K. Das, Charles River Analytics, Inc.; I. Kadar, Interlink Systems Sciences, Inc.; M. M. Kokar, Northeastern Univ.; J. Llinas, SUNY/Univ. at Buffalo; G. M. Powell, U.S. Army CERDEC I2WD; E. H. Ruspini, SRI International; J. J. Salerno, Air Force Research Lab.

Situation assessment (SA) involves estimation of relationships among entities. Relations can be classified as "aggregation", "subclass" or other generic relations. While SA has been recognized in the information fusion and human factors literature, there still exist open questions regarding knowledge representation and reasoning methods to afford SA. For instance, while lots of data is collected over a region of interest, how does this information get presented to a user that is attention constrained? The information overload can deteriorate cognitive reasoning so a pragmatic solution to knowledge representation is needed for effective and efficient situation understanding. In this paper, we present issues associated with Level 2 (Situation Assessment) including (1) perceptual reasoning, (2) knowledge discovery, (3) procedural versus logic reasoning, (4) user-fusion interaction through performance metrics, and (5) syntactic and semantic representations. While a definitive conclusion is not the aim of the paper, many critical issues are proposed in order to characterize future successful strategies to knowledge representation and reasoning strategies for situation assessment.

6235-39, Session 7

Effective behavioral modeling and prediction even when few exemplars are available

T. Goan, N. Kartha, Stottler Henke Associates, Inc.

While great progress has been made in the lowest levels of data fusion, practical advances in behavior modeling and prediction remain elusive. The most critical limitation of existing approaches is their inability to support the required knowledge modeling and continuing refinement under realistic constraints (e.g., few historic exemplars, the lack of knowledge engineering support, and the need for rapid system deployment). This paper reports on our ongoing efforts, funded by the Air Force Research Laboratory, to develop Propheteer, a system which will address these shortcomings through two primary techniques. First, with Propheteer we abandon the typical consensus-driven modeling approaches that involve infrequent group decision making sessions in favor of an approach that solicits asynchronous knowledge contributions (in the form of alternative future scenarios and indicators) without burdening the user with endless certainty or probability estimates. Second, we enable knowledge contributions by personnel beyond the typical core decision making group, thereby casting light on blindspots, mitigating human biases, and helping maintain the currency of the developed behavior models. In this paper we will discuss the many lessons learned in the development of our prototype Propheteer system as well as how this approach to modeling can lead to effective predictive systems in domains ranging from corporate competitive intelligence to military indications and warnings. We will also describe how Propheteer can motivate diverse knowledge contributions by supporting capabilities that go beyond the core threat prediction tasks such as current situation monitoring and context enhanced search.

6235-40, Session 7

Evaluation of hybrid fusion 2+ approach for providing air-to-air situational awareness and threat assessment

K. D. Lee, E. Wiesenfeld, M. Colony, Decisive Analytics Corp.

Modern combat aircraft pilots increasingly rely on high-level fusion models (JDL Levels 2/3) to provide real-time engagement support in hostile situations. These models provide both Situational Awareness (SA) and Threat Assessment (TA) based on data and the relationships between the data. This information represents two distinct classes of uncertainty: vagueness and ambiguity. To address the needs associated with modeling both of these types of data uncertainty, an innovative hybrid approach was recently introduced, combining probability theory and possibility theory into a unified computational framework. The goal of this research is to qualitatively and quantitatively address the advantages and disadvantages of adopting this hybrid framework as well as identifying instances in which the combine model outperforms or is more appropriate than more classical inference approaches. To accomplish this task, domain specific models will be developed using different theoretical approaches and conventions and evaluated in comparison to situational ground truth to determine their accuracy and fidelity. Additionally, the performance trades between accuracy and complexity will be examined in terms of computational cost to determine both the advantages and disadvantages of each approach.

6235-41, Session 7

Belief network-based situation assessment for air operations centers

P. G. Gonsalves, C. Call, Charles River Analytics, Inc.

In dynamic environments (e.g. an Air Operations Center (AOC)), effective real-time monitoring of mission execution is highly-dependent on situation awareness (SA). But whereas an individual's perception of mission progress is biased by his or her immediate tasks and environment, the combined perspectives of key individuals provides an overall effects-based assessment of the mission. Belief networks (BNs) are an ideal tool for modeling and meeting the requirements of SA: at the individual level BNs emulate a skilled human's information fusion and reasoning process in a multi-task environment in the presence of uncertainty. At the mission level, BNs are intelligently combined to yield a common operating picture. While belief networks offer significant advantages for SA, the work of specifying and combining the models is difficult due to factors such as multiple-counting and conflicting reports. To address these issues, we develop a system consisting of two distinct functional elements: an off-line mechanism for rapid construction of a BN library of SA models tailored to different air campaign situations and derived from knowledge elicitation with subject matter experts; and an on-line mechanism to adapt and combine the BN models. The adaptation supports the ability to adjust the SA models over time and in response to novel situations not initially available or anticipated during model construction. The combination of SA models supports an enhanced SA and the ability to monitor execution status in real time in a manner that is informed by and responsive to the individuals and situations involved.

6235-42, Session 7

Combination rules of evidence for situation assessment and target identification

H. Sun, M. Farooq, Royal Military College of Canada (Canada)

In this paper, the conjunctive and disjunctive combination rules of evidence, namely, the Dempster-Shafer's combination rule, the Yager's combination rule, the Dubois and Prade's combination rule, the Dsm's combination rule and the disjunctive combination rule, are applied to situation assessment and target identification. It is shown that the conjunctive and disjunctive combination rules of evidence yield superior results compared to other techniques. The paper will include realistic scenarios to demonstrate the application of the proposed techniques.

6235-43, Session 7

Higher category theory as a paradigm for network applications

J. R. Bonick, U.S. Army Night Vision & Electronic Sensors Directorate

The importance of network science to the present and future military is unquestioned. Networks of some type pervade every aspect of military operations-a situation that is shared by civilian society. However, several aspects of militarily oriented network science must be considered unique or given significantly greater emphasis than their civilian counterparts. Military, especially battlespace, networks must be mobile and robust. They must utilize diverse sensors moving in and out of the network. They must be able to survive various modes of attack and the destruction of large segments of their structure. Nodes often must pass on classifications made locally while other nodes must serve as combined sensor/classifiers or information coordinators. They must be capable of forming fluidly and in an ad hoc manner.

In this paper, it will be shown how category theory, higher category theory, and topos theory provide just the model required by military network science. Category theory is a well-developed mathematical field that views mathematical structures abstractly, often revealing previously unnoticed correspondences. It has been used in database and software modeling, and in sensor and data fusion. It provides an advantage over other modeling formalisms both in its generality and in its extensive theory. Higher category theory extends the insights of category theory into higher dimensions, enhancing robustness. Topos theory was developed, in part, through the application of category theory to logic, but it also has geometric aspects. The motivation behind including topos theory in network science is the idea that a mathematical theory fundamental to geometry and logic should be applicable to the study of systems of spatially distributed information and analysis flow. The structures presented in this paper will have profound and far-reaching applications to military networks.

6235-44, Session 8

A synergistic exploitation concept for wide-area search

M. J. Carlotto, General Dynamics Corp.

Key to effective image exploitation is letting man and machine do what they each do best. Automated target recognition (ATR) systems rely on model-based approaches that operate in a highly structured predict-extract-match-search (PEMS) loop. Fundamental to wide area search (WAS) is the problem of detecting a large number of potential objects that are so diverse in nature that they cannot be enumerated let alone modeled. In addition there is the problem of unexpected objects (i.e., those that cannot be modeled a priori). A new approach to search based on a detect-organize-compile (DOC) paradigm is proposed and applied to wide area change detection (WACD). It combines an automated image screening algorithm for detecting manmade changes with an interactive web-based tool for ranking, reviewing, and compiling changes of interest. Performance of this approach against exhaustive manual search of the image shows about a 10X increase in throughput (changes detected per unit time) at a fixed level of performance.

6235-45, Session 8

Automatic clustering based on an information-theoretic approach with application to spectral anomaly detection

M. J. Carlotto, General Dynamics Corp.

An information-theoretic method is described for automatically determining the best number of clusters. It is motivated by Rissanen's minimum

description length principle that states the best representation is the one with the fewest bits. The method is evaluated using two different clustering algorithms: a mode finder based on scale-space algorithm, and a vector quantizer (VQ). Synthetic, single- and multi-band image clustering examples are presented. Clusterings produced by the mode finder are shown to better correspond to distinguishable surface categories in the scene than those produced by the VQ algorithm. VQ clusterings are evaluated within an anomaly detector, which detects manmade object/changes as spectral outliers within a set of background clusters. It is shown that the optimal VQ clustering (the one with the fewest bits) produces the best detection performance.

6235-46, Session 8

A fully automated image co-registration system

D. A. Lavigne, Defence R&D Canada/Valcartier (Canada)

Current military surveillance and reconnaissance systems require improved capability to enable the co-registration of larger images combining enhanced temporal, spatial, and spectral resolutions. Traditional, manual exploitation techniques are not able to cope successfully with the avalanche of data to be processed and analyzed. Automated image exploitation tools can be used if images are automatically co-registered together, and thus ready to be analyzed by a further process. Such automated co-registration algorithms shall be able to deal with different military case scenarios, and helpful to be used successively in numerous applications such as image data fusion, change detection, and site monitoring.

This paper describes the Automated Multisensor Image Registration (AMIR) system and embedded algorithms developed at DRDC-Valcartier. The AMIR system provides a framework for the automated multi-date registration of electro-optic images acquired from different sensors. The system is original because it is fully automated and doesn't rely on any user interaction to operate. Advanced image algorithms are used in order to supply the capabilities to register multitemporal electro-optic images acquired from different viewpoints, under singular operational conditions, multiple scenarios (e.g. airport, harbor, vegetation, urban, etc.), different spatial resolutions (e.g. IKONOS/QuickBird, Spaceborne/Airborne), while providing subpixel accuracy registration level.

6235-47, Session 8

Automatic parameter selection for feature-based multisensor image registration

S. P. DelMarco, V. T. Tom, H. F. Webb, A. Chao, BAE Systems Advanced Information Technologies

Accurate image registration is critical for applications such as precision targeting, geo-location, change-detection, surveillance, and remote sensing. However, the increasing volume of image data is exceeding the current capacity of human analysts to perform manual registration. This image data glut necessitates the development of automated approaches to image registration, including algorithm parameter value selection. Proper parameter value selection is crucial to the success of registration techniques. The appropriate algorithm parameters can be highly scene and sensor dependent. Therefore, robust algorithm parameter value selection approaches are a critical component of an end-to-end image registration algorithm. In previous work, we developed a general framework for multisensor image registration which includes feature-based registration approaches. In this work we examine the problem of automated parameter selection. We apply the automated parameter selection approach of Yitzhaky and Peli to select parameters for feature-based registration of multisensor image data. The approach consists of generating multiple feature-detected images by sweeping over parameter combinations and using these images to generate estimated ground truth. The feature-detected images are compared to the estimated ground truth images to generate ROC points associated with each parameter combination. We develop a strategy for selecting the optimal parameter set by choosing the parameter combination corresponding to the optimal ROC point. We present numerical results showing the effectiveness of the approach using registration of collected SAR data to reference EO data.

6235-48, Session 9

Strictly positive definite correlation functions

J. T. Dolloff, B. A. Lofy, A. D. Sussman, C. R. Taylor, BAE Systems North America

Sufficient conditions for strictly positive definite correlation functions are developed. These functions are associated with wide-sense stationary stochastic processes and provide practical models for various errors affecting tracking, fusion, and general estimation problems. In particular, the expected magnitude and temporal correlation of a stochastic error process are modeled such that the covariance matrix corresponding to a set of errors sampled (measured) at different times is positive definite (invertible) - a necessary condition for many applications. The covariance matrix is generated using the strictly positive definite correlation function and the sample times. As a related benefit, a large covariance matrix can be naturally compressed for storage and dissemination by a few parameters that define the specific correlation function and the sample times. Results are extended to wide-sense homogeneous multi-variate (vector-valued) random fields. Corresponding strictly positive definite correlation functions can statistically model fiducial (control point) errors including their inter-fiducial spatial correlations. If an estimator does not model correlations, its estimates are not optimal, its corresponding accuracy estimates (a posteriori error covariance) are unreliable, and it may diverge. Finally, results are extended to approximate error covariance matrices corresponding to non-homogeneous, multi-variate random fields (a generalization of non-stationary stochastic processes). Examples of strictly positive definite correlation functions and corresponding error covariance matrices are provided throughout the paper.

6235-49, Session 9

LAM: a landscape matching algorithm for respiratory data alignment

L. Chen, T. McKenna, U.S. Army Medical Research and Materiel Command; A. Reisner, Massachusetts General Hospital; J. Reifman, U.S. Army Medical Research and Materiel Command

Noisy and misaligned respiratory data collected from life sign devices impede robust and accurate data mining. Misalignment of respiratory waveforms and their derived rates may result from interruptions in the synchronization between recording of the waveforms and the rates, or errors in the data archiving process. Realignment of respiratory waveforms and rates can be achieved by aligning independently calculated rates from the waveforms and the monitor provided rates. However, substantially different rates may be generated from the same waveform due to subjective evaluation of ambiguous breaths at noisy positions. This paper reports a landscape adjusted matching (LAM) algorithm to align respiratory rate series calculated from different sources. The algorithm exploits the intermittent matches between two respiratory rate series to generate a matching score for an alignment. The best alignment exhibits the highest matching score. The accuracy of the LAM algorithm is evaluated in a comparison to a correlation matching (CM) algorithm using real respiratory data. Performance of the alignments is evaluated by: (1) a comparison of the percent match of the respiratory rates between alignment results from the two algorithms; and (2) a comparison of the ability of the two algorithms to return a shifted waveform to its original position. The LAM alignment algorithm outperforms the CM algorithm in both comparisons at a statistically significant level ($p<0.05$). Out of 474 samples, LAM performs better, worse, and equal in percent match to the CM algorithm in 74%, 22%, and 4% of the cases, respectively. Out of 579 samples, LAM generates shift positions closer, further, and equal in distance from known positions than does the CM algorithm in 55%, 41% and 4% of the cases, respectively. This robust respiratory rate alignment algorithm enables the use of reliable post-hoc monitor-provided data for data mining purposes.

6235-50, Session 9

Proximity graph analysis for linear networks extraction from high-resolution satellite imagery

A. N. Skourikhine, Los Alamos National Lab.

Reliable and accurate methods for detection and extraction of linear network, such as road networks, in satellite imagery are essential to many applications. We present an approach to the road network extraction from high-resolution satellite imagery that is based on proximity graph analysis. We are jumping off from the preliminary classification provided by existing spectral and textural classification tools, which would produce a first rough road detection result containing a set of candidate road fragments. Then, these fragments would be processed by Chordal axis transform (based on constrained Delaunay triangulation) to extract attributed center lines corresponding to the fragments. Due to unavoidable noise in the contour boundaries enclosing the detected fragments, the produced centerlines would contain many branches irrelevant to the road fragment representation. These noisy centerlines would be refined using our object decomposition techniques. The result is a set of refined center lines containing all the information describing corresponding fragments, like width and length. This set of refined center lines also serves as a vector representation of the detected road fragments, reducing amount of information to be analyzed at the following stages and making road network reconstruction easier. Refined center lines are triangulated using a constrained Delaunay triangulation algorithm to generate a sub-optimal mesh of interconnections among them. The edges generated by the triangulation, that lie between different center lines, could be used to evaluate smoothness, continuity, proximity, and other relations between various center lines. Then, based on the obtained Delaunay triangular mesh, the first approximation of road network can be obtained by using only proximity relations between the fragments as it is expected that road fragments would be closer to each other. As a result, the use of graph algorithm, such as the Euclidian Minimum Spanning Tree (EMST), would produce a network connecting all the fragments, where the overall length of the network is minimal. The approach is applied to real images for validation. We also discuss some issues about extending our approach to multicriteria semiautomatic road network extraction by including other interfragments structural relations in addition to the proximity.

6235-51, Session 9

Image fusion for improved perception

M. Ouendeno, S. P. Kozaitis, Florida Institute of Technology

We combined imagery that leads to improved extraction of information from disparate sensors. The aim is to extract useful information from source images by combining them into a single image without introducing artifacts nor any consistencies which distract human observers. With the near shift-invariant property of the Stationary Wavelet Transform and the consistency of coefficients through different scales, we are able to get useful edge information needed for the fusion. Using the method described here, we expect to reconstruct a fused image that will retain the information content in disparate domains while enhancing the information content of the fused image product. With this information, we are able to construct a Fusion Decision Map; that is, not only the information of each edge pixel and it close neighbors, but also the regions the coefficients are in. Finally, the fused image is created by the inverse transform of Stationary Wavelet Transform.

6235-52, Session 9

Hue-saturation-value feature analysis for robust ground moving target tracking in color aerial video

S. M. Matechik, V. E. Zetterlind III, A. B. Johnson, The MITRE Corp.

Ground moving target tracking in aerial video presents a difficult algorithmic challenge due to sensor platform motion, non-uniform scene illumination, and other extended operating conditions. Theoretically, trackers which operate on color video should have improved performance vs. monochromatic trackers by leveraging the additional intensity channels. In this work, ground moving targets in color video are characterized in the Hue-Saturation-Value (HSV) color space. Using segmented real aerial video, HSV statistics are measured for multiple vehicle and background types and evaluated for separability and invariance to illumination change, obscuration, and aspect change. The statistics are then recalculated for moving targets from the same video segmented with existing color tracking algorithms to determine HSV feature robustness to noisy segmentation.

6235-53, Session 9

Secure and robust data hiding in binary images

S. S. Agaian, R. C. Cherukuri, The Univ. of Texas at San Antonio

Steganography is an art of sharing a secret message or data between two authorized users without revealing the presence to any of the third party viewers. Technically, it is an art of secret communication. Most of the prior works were proposed for color, gray scale images, where changing the pixel value by a small amount may not noticeable. Hiding data in the binary images is difficult because any modification made to the pixels directly could change the image significantly. There are only a few articles for embedding into binary images. Most of the works proposed are based of constant embedding from block to block because of which they could not capitalize on uneven embedding capacity from block to block.

In this paper, we investigate the following issues

1.How to select pixels for manipulation so as to embed information with would introduce minimal visual changes to the cover.

2.How to enforce a relation ship between the blocks bits and a secret key so as to embed information securely into the cover.

3.How to embed a varying number of bits from block to block.

The proposed algorithm enhances the security secured data embedded into a binary cover image by limiting the altered pixels to edges only. We test the performance of the algorithm over 50 various sizes of binary cover images embedding various sizes of secured data. Comparisons with existing algorithms will be presented.

6235-54, Session 10

Comparing artificial and biological dynamical neural networks

A. D. McAulay, Lehigh Univ.

A tap from the output of an artificial feed-forward neural network is fed back to an input to produce a dynamical neural network. Two such networks, ignoring other inputs, are coupled by feeding the output of one back to the input of the other and vice versa. As a result a separate input to one of the networks can control the output in a supercritical Hopf bifurcation so that the output can be in only one of two states: totally off, or in a stable limit cycle whose frequency and magnitude are controlled by the input magnitude.

This is shown by analyzing the equations and performing simulations. This system is compared to the commonly used Wilson-Cowan model for biological neural networks. We discuss how this model can perform useful thresholding and associative memory functions. Other bifurcations are discussed with their possible applications. In previous SPIE papers we showed optical implementations of learning systems: in (McAulay Orlando April 2005, this conference last year) we showed optical clustering of microrings for unsupervised learning and in (McAulay 5908-15 Aug. 2005) we showed that an injected laser diode can also exhibit Hopf bifurcations similar to those in this paper.

6235-55, Session 10

Using self-organizing maps to determine observation threshold limit predictions in highly variant data

C. Paganoni, Science Applications International Corp.; K. C. Chang, George Mason Univ.; M. Robblee, U.S. Geological Survey

A significant data quality challenge for highly variant systems surrounds the limited ability to quantify operationally reasonable limits on the data elements being collected and provide reasonable threshold predictions. In many instances, the number of influences that drive a resulting value or operational range is too large to enable physical sampling for each influencer, or is too complicated to accurately model in an explicit simulation. An alternative method to determine reasonable observation thresholds is to employ an automation algorithm that would emulate a human analyst visually inspecting data for limits. By employing the visualization technique of self-organizing maps (SOM) on data that has established but poorly understood relationships, a methodology for determining threshold limits was developed. Using multiple individual SOMs, each having its own estimate of a threshold limit for an observed outcome, and fusing their results, an aggregate estimate of the effect on an observation value was generated.

To illustrate this approach, analysis of environmental influences that drive survivability of a target indicator species (Farfantepenaeus duorarum - or pink shrimp) provided a real example of applicability. The relationship between salinity and temperature and abundance of F. duorarum is well documented in that region, but prediction of the impact due to changes in water quality upstream is not well understood. The highly variant nature surrounding the capture of a specific number of organisms in the wild, and the large amount of data available surrounding the up-stream hydrology measures for salinity and temperature made this an ideal candidate for using the SOM approach for analysis. Environmental sampling data from continuously monitored hydrology stations in Florida Bay were fused together to produce a determination about the influence of salinity and temperature changes on populations of organisms in that region was generated.

6235-56, Session 10

Measures of effectiveness for analysis of radar pulse train deinterleavers

M. J. Thompson, S. Lin, J. C. Sciortino, Jr., Naval Research Lab.

This paper will compare the various methods of analyzing the results of radar pulse train deinterleavers. This paper will be in three sections. The first section of this paper will describe the basic methods, such as the confusion matrix, and some measures that can be obtained from the matrix. The measures will include correct correlation, miscorrelation, ambiguity and track purity. Correct correlation is calculated by dividing the total number of correctly clustered pulses by the total number of pulses in the collect. Miscorrelation measures the fraction of received pulses that incorrectly deinterleaved. Ambiguity measures the fraction of received pulses that are rejected by the deinterleaver as having uncertain association with a ground truth track. Track purity measures the ability of the deinterleaver to create a constructed track comprised of pulses from a single ground truth track. These metrics will show the quality of the deinterleaving operation.

The second section of this paper will describe some of the advanced similarity measures of effectiveness. This section will also describe how distance measures will be used to analyze deinterleaver results. The two main similarity measures to be discussed in this paper will be the rand adjust and Jaccard coefficient. These similarity measures are also known as criterion indices and are used for evaluating the capacity to recover true cluster structure. The reason for the selection of the Jaccard and Rand Adjust as measures is that they both allow a value to be obtained that is between 0 and 1 that will show how good the clusterer in question has performed. The Rand Adjust also allows for more variability in the range between 0 and 1 and appears to provide a more accurate evaluation of the cluster. The distance measures that will be described include Euclidean, Mahalanobis and Minkowski distances. These distance measures have different methods to evaluate each cluster for purity. These measures will provide an indication of the quality of the deinterleaver operation.

The third section of this paper will provide the results from these measures on a deinterleavered dataset and will discuss the comparison of these metrics.

6235-57, Session 10

Transition matrices for the detection and removal of signal contamination in deinterleaved pulse trains

D. C. Black, Naval Research Lab.; J. R. Altoft, Altek Systems Research LLC (Canada); J. C. Sciortino, Jr., Naval Research Lab.

Purity of deinterleaved pulse descriptor word (PDW) trains is critical to the performance of emitter classification software that analyzes PDW data. Contamination of the input PDW train can lead to artifacts in the analysis resulting in incorrect or ambiguous classification. In this paper, we investigate the possibility of applying transition matrices to the detection and removal of contaminating pulses from a deinterleaver output. The utility of transition matrices as a fast and efficient pattern recognition tool in ESM emitter classification has been known for over a decade [Brown, R.G., “Pattern Recognition Using Transition Matrices”, .7th RMC Symposium on Applications of Advanced Software in Engineering, pp 52-57, Royal Military College of Canada, Kingston Ontario, May 1995]. In this work, we seek patterns unique to contaminated PDW trains that can provide a warning that a particular PDW train is contaminated, and provide a clue as to which pulses should be removed to purify the PDW train.

6235-58, Session 10

A comparison of TOA wersus multiple parametric based radar pulse train deinterleavers

S. Lin, M. J. Thompson, Naval Research Lab.; S. Davezac, Innovative Logistics Techniques, Inc.; J. C. Sciortino, Jr., Naval Research Lab.

This paper provides a comparison of the two main techniques currently in use to solve the problem of radar pulse train deinterleaving. Pulse train deinterleaving separates radar pulse trains into the tracks or bins associated with an emitter. The two techniques are simple time of arrival (TOA) histogramming and multi-parametric analysis. Multi-parametric analysis utilizes any combination of the following parameters: TOA, radio frequency (RF), pulse width (PW), and angle of arrival (AOA). These techniques use a variety of algorithms, such as fuzzy adaptive resonance theory, integrated adaptive fuzzy clustering, fuzzy min-max clustering, direction of arrival analysis with RF pulse filtering and fuzzy adaptive resonance theory map to compare the pulses to determine if they are from the same emitter. This deinterleaving is critical since inaccurate deinterleaving can lead to misidentification of emitters.

The deinterleaving techniques evaluated in this paper are a sizeable and representative sample of both US and international efforts developed in the UK, Canada, Australia and Yugoslavia. Mardia [1989] and Milojevic and Popovich [1992] shows some of the early work in TOA-based deinterleaving. Ray [1997] demonstrates some of the more recent work in this area. Multi-parametric techniques are exemplified by Granger, et al [1998], and Thompson and Sciortino [2004]. This paper will provide an analysis of the algorithms and discuss the results obtained from the referenced articles. The algorithms will be evaluated for usefulness in deinterleaving pulse trains from agile radars.

6235-59, Session 10

Performance measures for parameter extraction of sensor array point targets using the discrete chirp Fourier transform

N. G. Santiago, C. Aceros, D. Rodriguez, Univ. de Puerto Rico Mayagüez

This work presents a new methodology to assist in the mapping of new large scale discrete chirp Fourier transform (DCFT) algorithms to high performance computers using novel Kronecker products formulations. The DCFT algorithms are utilized in time-frequency signal analysis techniques for target detection. These techniques center on the fusion of time-frequency information, acquired from transformed chirp or linear FM signals using the DCFT, with information obtained when the signals are treated using the discrete ambiguity function acting as point target response, point spread function, or impulse response of an active sensor array system such as a synthetic aperture radar array system. MPI-based parallel implementions have been obtained on cluster computers.

The proposed methodology applies well-defined design of experiments methods to the identification of relations among different levels in the process of mapping computational operations to high-performance computing systems. The use of statistics for identification of relationships among factors has formalized the solution of the problem and this approach allows unbiased conclusions about results. Subset selection based on principal components was used to determine the subset of metrics required to explain the behavior of the system. This methodology is divided in four steps. First, a preliminary problem analysis to visualize in general what is affecting the performance of the application. The second step is to specify the experiment design to collect enough unbiased information in order to be analyzed for establishing relationships. The third step is to collect the data. The fourth and last step is for data analysis.

6235-60, Session 10

Multiplicative mismatched filter for optimum sidelobe suppression in Barker codes

A. T. Fam, I. Sarkar, SUNY/Univ. at Buffalo

Barker codes are the only known bi-phase codes with the smallest achievable sidelobes. However, the largest known Barker code is of length 13 with a strong conjecture that no Barker code of longer length exists. The code of length 13 achieves a mainlobe to peak sidelobe ratio of only 22.28 dB which is less than the practical requirement of at least 30 dB. Mismatched filters have been proposed in the literature to improve this ratio. This is achieved at the cost of some deterioration in the signal to noise ratio at the filter output.

In this paper, we achieve very efficient sidelobe suppression of Barker codes of length 13 through the use of a novel mismatched filter. The mismatched filter is comprised of a conventional matched filter cascaded with a computationally efficient filter based on multiplicative expansion. The combination is shown to achieve a mainlobe to peak sidelobe ratio of almost 60 dB. This large amount of sidelobe suppression is achieved using 101 adders and only 15 multipliers. The loss in signal to noise ratio is shown to be only 1.2 dB.

It is suggested that by applying the technique to compound Barker codes, the mainlobe to peak sidelobe ratio could be maintained and the signal to noise ratio performance could be improved. Application of the proposed approach to generalized Barker codes with complex coefficients and sidelobes with magnitudes less than unity is also considered in this paper.

6235-62, Poster Session

Tropospheric aerosols remote sensing over the water surface of Penang Island

C. J. Wong, Univ. Sains Malaysia (Malaysia)

Tropospheric aerosols play an important role in climate change. Aerosols are typically studied over water, due to the relatively constant reflectance of water and the ability to easily separate surface and atmospheric contributions on the satellite signal. A methodology based on multi-spectral approach was employed to map tropospheric aerosols concentrations over the water areas surrounding Penang Island. The aim of this study was to estimate the pollutants concentrations using remote sensing techniques. Multi-spectral image (three bands, assigned as red, green and blue) from Landsat TM was used in this study. The particulate matter sizing less than 10-micron (PM10) readings were collected simultaneously during the acquisition of the imageries. The remote sensing signals corresponding to the PM10 measurements were converted from digital numbers into reflectance values for algorithm regression. The algorithm that was developed based on the atmospheric optical characteristic was used to correlate the digital signals and the PM10 concentrations. The proposed algorithm produced a high correlation coefficient (R) and the low root-mean-square error (RMSE). The PM10 concentration map over the water surface of Penang Island was generated.

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6236-01, Session 1

Novel nonlinear adaptive Doppler shift estimation technique (NADSET) for the coherent Doppler lidar system VALIDAR

J. Y. Beyon, California State Univ./Los Angeles; G. J. Koch, NASA Langley Research Ctr.

A novel Nonlinear Adaptive Doppler Shift Estimation Technique (NADSET) is introduced in this paper. The quality of Doppler shift and power estimations by conventional Fourier-transform-based spectrum estimation methods deteriorates rapidly in low signal-to-noise-ratio (SNR) environment. The new NADSET compensates such deterioration in the quality of wind parameter estimates by adaptively utilizing the statistics of Doppler shift estimate in a strong SNR range and identifying sporadic range bins where good Doppler shift estimates are found. The NADSET is based on the nature of continuous wind profile and dramatically improves the accuracy and quality of Doppler shift estimate in low SNR ranges. The authenticity of NADSET is established by comparing the trend of wind parameters with and without applying NADSET to the lidar returns acquired over a long period of time by the coherent Doppler lidar system VALIDAR at NASA Langley Research Center in Virginia.

6236-02, Session 1

Analysis of subbanding techniques in blind source separation

J. A. Kolba, I. I. Jouny, Lafayette College

In this paper, we seek to study the impact of subbanding on blind source separation (BSS) as it could apply radar signals. We will focus on comparing wavelet-based subbanding, uniform subbanding, and no subbanding. For performing the BSS, we will use two popular algorithms: joint approximate diagonalisation of eigen-matrices (JADE) and second-order blind identification (SOBI). As the measure of performance, we will use the interference to signal ratio.

6236-03, Session 1

Tracking subpixel targets in domestic environments

V. Govinda, J. F. Ralph, J. W. Spencer, J. Y. Goulermas, The Univ. of Liverpool (United Kingdom)

In recent years, closed circuit cameras have become a common feature of urban life. There are environments, however, where the movement of people needs to be monitored but high resolution imaging is not necessarily desirable: rooms where privacy is required and the occupants are not comfortable with being 'watched'. Examples might include domiciliary care environments, prisons and other secure facilities, and large open plan offices. This paper discusses algorithms that allow activity within this type of sensitive environment to be monitored using data from very low-resolution cameras (ones where all objects of interest are sub-pixel and cannot be resolved) and other non-intrusive sensors. The algorithms are based on techniques originally developed for wide area reconnaissance and surveillance applications. Of particular importance is determining the minimum spatial resolution that is required to provide a specific level of coverage and reliability.

6236-05, Session 1

Wind profiling by a coherent Doppler lidar system VALIDAR with a subspace decomposition approach

J. Y. Beyon, California State Univ./Los Angeles; G. J. Koch, NASA Langley Research Ctr.

The current nonlinear algorithm for the coherent Doppler lidar system VALIDAR at NASA Langley Research Center estimates wind parameters such as Doppler shift, power, wind velocity and direction by locating the maximum power and its frequency from the periodogram of the stochastic lidar returns. Due to the nonlinear nature of the algorithm, mathematically tractable parametric approaches to improve the quality of wind parameter estimates may pose little influence on the estimates, especially in low signal-to-noise-ratio (SNR) regime. This paper discusses an alternate approach to accurately estimate the nonlinear wind parameters while preventing ambiguity in decision-making process via the subspace decomposition of wind data. By exploring the orthogonality of noise and signal subspaces expanded by the eigenvectors corresponding to the eigenvalues representing each subspace, a single maximum power frequency is estimated while suppressing erroneous peaks that are always present with conventional Fourier-transform-based frequency spectra. The subspace decomposition approach is integrated into the data processing program for VALIDAR in order to study the impact of such approach in wind profiling with VALIDAR.

6236-06, Session 1

Time-frequency methods for detection and classification of buried targets

E. J. Kaminsky Bourgeois, M. Barbu, Univ. of New Orleans; L. D. Bibee, Naval Research Lab.

This paper presents the development and evaluation of time-frequency processing techniques for detection and classification of buried objects from parametric sonar data. The software system was designed to discriminate between various targets of interest including long targets such as cables and point targets buried a few meters deep in the ocean sediment. The sonar in question, PARADISE (Parametric Detection and Imaging Sensor), consists of three parametric hydrophones simultaneously pinging at a high speed imposing tough requirements on real-time processing capabilities.

The fractional Fourier transform of optimum order is estimated based on the properties of the transmitted chirp signal. Features are then extracted from the Wigner distribution of the bottom impulse response. Principal component analysis (PCA) is then used to reduce the dimensionality of the feature space by removing correlation among features and then discarding those components which contribute the least to the overall variance.

Synthetic and actual test data are used to exemplify the techniques. Results are presented that illustrate the processing procedure and show that these techniques provide accurate ways to detect and classify buried objects with high probability of correct classification and low false alarm rates.

6236-07, Session 1

Peak inspecting and signal recovery methods based on triple correlation

H. Cao, Huazhong Univ. of Science and Technology (China)

Weak target inspecting and recovering are very important for image processing in IR detecting systems. Generally in IR detecting systems, matched filtering technique is used in order to restrain noise and get the maximal output signal-to-noise ratio. This technique is actually a matching filter in the domain of the second order correlation, and the maximum output SNR is limited by the power spectrum of noises. In order to improve performances and increase the range of IR detecting systems, it is necessary to further investigate and overcome the limitation of "maximum output SNR" of second order matching filter in image processing. Especially, it is necessary to search a new approach of identifying and distinguishing a sub-pixel target and a point target from a low SNR image. With the concept and the features of a higher order moment, this problem can be solved probably.

In this paper, new approaches based on triple correlation peak inspecting technique(TCPIT) have been presented to extract target signal information from noises effectively. Meanwhile, the triple correlation overlapping sampling technique(TCOST) is advanced for restoring signal waveforms of IR detection systems.

Investigations show that the signal-to-noise ratio(SNR) improvement of approximate 23 dB can be obtained using TCPIT approach in the input peak SNR of 0.84 and the input power SNR of -9.73 dB. Investigations show also that the method based on TCOST can effectively restore signal waveforms in the low SNR circumstances (for example, the input peak SNR is 0.7352272).

6236-45, Session 1

Surveillance radar range-bearing centroid processing, part II: pulse compression waveforms and merged measurement processing

B. J. Slocumb, Numerica Corp.

In non-monopulse mechanically scanned surveillance radars, each target can be detected multiple times as the beam is scanned across the target. To prevent redundant reports of the object, a centroid processing algorithm is used to associate and cluster the multiple detections, called primitives, into a single object measurement. At the 2001 SPIE conference, Part I of this paper was presented wherein a new recursive least squares algorithm was derived that produces a range-bearing centroid estimate. In this Part II paper, the problem will be revisited to address two aspects of the problem that were not considered in the Part I paper. One issue is the use of a pulse compression waveform, and the associated need to apply an interpolation algorithm to estimate the target range from samples on the pulse compression filter output. The second issue to be addressed is the development of methods to parse merged measurements that result from the presence of closely-spaced targets.

6236-08, Session 2

Improved target tracking using track quality measures

A. Sinha, T. Kirubarajan, McMaster Univ. (Canada); Z. J. Ding, Raytheon Canada Ltd. (Canada)

In multitarget tracking in addition to the problem of measurement-to-track association, which is typically solved using assignment or matching algorithms, there are other decision-oriented problems in track initialization, confirmation and termination. In general, such decisions are taken based on the total number of measurement associations, length of unassociated sequences and total life of the track in question. In order to better utilize the available information from the past tracks and current measurements, confidence of the tracker on a particular track can be used. This quantity can be measured from the measurement-to-track association likelihoods corresponding to the particular track, target detection probability for the sensor-target geometry and false alarm density.

In this work we propose a multitarget tracker based on track quality measures. Here, the track quality is assumed to be equal to the tracker's belief in the existence of a particular track. In order to achieve this, we propose a new definition of the probability of track existence. Based on their quality and stage in track life, the established tracks are divided into a number of classes which are updated separately. The results show that discriminating tracks on the basis of track quality can lead to longer track life without increasing the number of false tracks or false associations after the termination of a valid track.

6236-09, Session 2

Map-enhanced tracking II

D. D. Sworder, Univ. of California/San Diego; J. E. Boyd, Cubic Defense Systems, Inc.; R. G. Hutchins, Naval Postgraduate School

In many applications, an LGM-model is used to describe the motion of a maneuvering target. Model-based estimation algorithms have proved useful in aerial applications. Hybrid-model (HM) approaches have improved performance of such trackers when the target has distinguishable motion modes. The hybrid-model representation uses a family of local models, each with a relatively small exogenous forcing term, to create a nuanced global model.

Even with multiple LGM-models, motions with tight topographic constraints are usually not well represented; e.g., when describing a target moving on an urban road grid. The local models in the HM framework have reduced broadband kinematic noise, but this is incompatible with the abrupt accelerations that occur when the target turns.

A road map is potentially useful for urban tracking in a low SNR environment. If properly integrated into the tracker, the map can be used to correct errors that accrete as the target moves between events distinguishable on the map. The map localizes permissible motions; e.g., the possible X-coordinates of N/S streets, and it establishes the coordinates of possible directional changes; e.g., placement of corners and junctions. Proper fusion of the kinematic measurements with the complementary map information is, however, made difficult by the incongruity of the separate data sets. This paper extends the work presented at last year's conference and presents a modified version of the Gaussian Wavelet Estimator (GWE) that accommodates to more detailed map constraints. It is shown by example that this map-enhanced GWE improves the accuracy of the location estimates and contracts the calculated uncertainty regions.

6236-10, Session 2

Identification of missile guidance laws for missile warning systems applications

J. F. Ralph, The Univ. of Liverpool (United Kingdom); M. I. Smith, J. P. Heather, Waterfall Solutions Ltd. (United Kingdom)

The reliable detection and tracking of missile plumes in sequences of infrared images is a crucial factor in developing infrared missile warning systems for use in military and civil aircraft. In this paper, we discuss the development of a set of algorithms that allow missile plumes to be detected, tracked and classified according to their perceived motion in the image plane. The aim is to classify the missile motion so as to provide an indication of the guidance law which is being used and, hence, to determine the type of missile that may be present and allow the appropriate countermeasures to be deployed. The algorithms allow for the motion of the host platform and they determine the missile motion relative to the fixed background provided by the scene. The tracks produced contain sufficient information to allow good discrimination between several standard missile types.

6236-11, Session 2

Tracking performance constrained MFR parameter control: applying constraint violation control

J. H. Zwaga, H. Driessen, Thales Nederland B.V. (Netherlands)

An efficient Multi Function Radar (MFR) parameter control for single target tracking would minimize the amount of radar resources needed for maintaining the required tracking performance. We have shown that the problem of finding this efficient MFR parameter control can be tackled by formulating it as a constrained minimization problem. The optimal MFR parameter control is subsequently obtained by solving this constrained minimization problem numerically.

This method for constrained MFR parameter control has been reported on both for the case of a requirement on track accuracy after updating, i.e. the filtering accuracy ([Zwaga, Boers and Driessen, FUSION2003] and [Boers, Driessen and Zwaga, Small Targets 2005]), and for the case of a requirement on the prediction accuracy, i.e. the track accuracy before updating ([Zwaga and Driessen, FUSION2005]).

[Zwaga, Boers and Driessen, FUSION2003] included an example with constraint violation control. In this paper, results of further research into constraint violation control are reported. As it turns out, the very fact that constraint violation control is applied, implies that an improvement over the original method for constrained MFR parameter control can be obtained. The original method for MFR parameter control is such that the expected tracking performance, taking into account the probability of a miss, meets the constraint on tracking performance. When however explicit constraint violation control is applied, we control the probability of the next measurement or group of measurements not resulting in a detection. Regarding the control of the expected tracking performance, we therefore no longer have to take the probability of a miss into account. As such, the resulting tracking performance will be much closer to the constraint, naturally requiring less radar resources.

Simulation results will show that this method indeed allows for constraint violation to be controlled. Furthermore, it is shown that with respect to the original method and with respect to a typical conventional MFR parameter control, a lower amount of radar resources is needed.

6236-12, Session 2

Maximum likelihood geolocation and track initialization using a ground moving target indicator (GMTI) report

M. K. Mallick, P. Steiber, Toyon Research Corp.

The ground moving target indicator (GMTI) radar sensor plays an important role in surveillance and precision tracking of ground moving targets. We consider two measurement models for the GMTI sensor. The measurements for the conventional measurement model are range, azimuth, and range-rate. Although the errors in the range and azimuth are correlated, the conventional model ignores this correlation. The measurements for an improved measurement model are range, path difference, and range-rate, where the measurement errors are uncorrelated. An initial estimate of the target state and associated covariance are required in the tracking filter using the first GMTI report. The sensor position, velocity, terrain elevation data, and geoid undulation are also used to determine the initial estimate. Our previous work on GMTI geolocation used an approximate method. This paper presents an improved algorithm for geolocation and filtering for ground moving targets. We extend our previous work on maximum likelihood (ML) geolocation using the improved algorithm. The ML geolocation and associated covariances for the two GMTI measurement models use covariances of errors in measured sensor state (position and velocity) and terrain data in addition to the GMTI measurement error covariances. We derive the Cramér-Rao lower bounds for the geolocation covariances using the two GMTI measurement models and evaluate the geolocation algorithms using simulated data. GMTI track initialization utilizes GMTI geolocation.

6236-13, Session 2

Surface to air missile aim identification

V. C. Ravindra, X. Lin, L. Lin, Y. Bar-Shalom, Univ. of Connecticut; S. R. Gottesman, Northrop Grumman Corp.

This work deals with the following question: using passive (line-of-sight angle) observations of a multistage missile from an aircraft, how can one infer that the missile is or is not aimed at the aircraft. The observations are assumed to be made only on the initial portion of the missile's trajectory. The approach is to model the trajectory of the missile with a number of kinematic and guidance parameters, estimate them and use statistical tools to infer whether the missile is guided toward the aircraft. A mathematical model is presented for a missile under pure proportional navigation with a changing velocity (direction change and speed change), to intercept a nonmaneuvering aircraft. A maximum likelihood estimator (MLE) is used for estimating the missile's motion parameters and a goodness-of-fit test is formulated to test if the aircraft is the aim or not. Using measurement data from several realistic missiles - single stage as well as multistage - aimed at an aircraft it is shown that the proposed method can solve this problem successfully. The key to the solution, in addition to the missile model parametrization, is the use of a reliable global optimization algorithm for the MLE. The estimation/decision algorithm presented here can be used for an aircraft to decide, in a timely manner, whether appropriate countermeasures are necessary.

6236-14, Session 2

Monitoring of sensor covariance consistency

S. S. Krigman, M. L. Smith, MIT Lincoln Lab.

In this paper we will define what we mean by filter and covariance consistency and will present the methodology for its verification (monitoring). This methodology has been applied to field data collected by several BMDS sensors. We will demonstrate it with simulated data sets representing some of these sensors. The methodology (inspired by discussion in book by Bar-Shalom and Li) relies on statistical hypothesis testing of Mahalonobis distances computed for innovation vectors and state vectors. Using these simulated data sets we will demonstrate the problems encountered with testing the innovation vectors in the presence of sensor biases. These problems underscore the need to focus the tests on the state vectors instead. Techniques for possible real time compensation for filter inconsistency will also be discussed.

6236-15, Session 2

Weiss-Weistein lower bound for maneuvering target tracking

T. Sathyan, McMaster Univ. (Canada); M. L. Hernandez, QinetiQ Ltd. (United Kingdom); T. Kirubarajan, A. Sinha, McMaster Univ. (Canada)

In target tracking, performance bounds are useful in characterizing the performance of suboptimal tracking algorithms. Recently, they have also been used in applications such as system design and online sensor management. Typically, the choice for the performance bound is the posterior Cramer-Rao lower bound (PCRLB). This is primarily due to the availability of a computationally efficient recursive formulation of the bound. But it has been shown that this bound is weak in certain applications.

Weiss-Weinstein lower bound (WWLB) is another second-order error bound that is free of regularity conditions and it can be applied for wider classes of problems. In addition, it has free variables that can be tuned to get tighter bounds. Further, a computationally efficient recursive forumation is available for the calculation of WWLB.

In this paper, we develop two version of the WWLB for maneuvering target tracking. In the first version, at each time step, the multi-modal prior target distribution is replaced by a best fitting Gaussian approximation. In

the second version, we utilize the ability of the WWLB to handle continuous and discrete random variables: in this version the state vector is augmented to the target motion model and the bound is calculated over the continuous and discrete state variables. In both cases, the bound is tightened using the available free variables. The results are compared with the PCRLB.

6236-16, Session 3

Enhanced multiple model tracker based on Gaussian mixture reduction for maneuvering targets in clutter

P. S. Maybeck, M. C. Kozak, Air Force Institute of Technology

The problem of tracking targets in clutter naturally leads to a Gaussian mixture representation of the probability density function of the target state vector. Research reported previously reveals that a tracker using an integral square error (ISE) based mixture reduction algorithm can provide performance which is significantly better than any other known techniques using similar numbers of mixture components. One useful tracking algorithm architecture for targets exhibiting very different trajectory characteristics over time would replace each Kalman filter within a conventional MMAE or IMM with an ISE-based algorithm that assumes the adequacy of the same particular dynamics model and discretized parameter choice ("mode"). The performance of such algorithms is evaluated, and compared to that of the corresponding MMAE or IMM based on Kalman filters in the same scenario except for being clutter-free. Comparison to other competing algorithms for the tracking of maneuvering targets in clutter is also performed.

Preliminary analyses indicated the extreme importance of proper gating for maximum performance benefit. This effort particularly investigates this essential issue, concentrating on the impact of conceiving of the algorithm architecture as an ISE algorithm of MMAE's rather than an MMAE of ISE filters when accomplishing that gating. Performance enhancement is shown to be significant by performing a tradeoff analysis with alternative gating techniques.

6236-17, Session 3

Quasi-Monte Carlo particle filters: the junk filter

F. E. Daum, Raytheon Co.

We describe a new particle filter that uses quasi-Monte Carlo (QMC) sampling with product measures rather than boring old Monte Carlo sampling or naive QMC or QMC with randomization. Product measures for QMC were recently invented by M. Junk & G. Venkiteswaran (August 2005), and therefore we call this new filter the Junk filter. Standard particle filters use boring old Monte Carlo sampling, which suffers from the curse of dimensionality. Monte Carlo sampling converges at the sluggish rate of c(d)/sqrt(N), in which c(d) is a strong function of dimension (d) and N is the number of particles. Oh's theory and numerical experiments (by us) show that for good proposal densities, c(d) grows as d^3, whereas for bad proposal densities, c(d) grows exponentially with d. In contrast, QMC converges much faster than MC with N. In particular, QMC converges as k(d)/N, in which k(d) is logarithmic in N and its dependence on d is similar to Oh's theory for MC sampling. This theory suggests that QMC is vastly superior to boring old MC sampling, but in practice for particle filters, naive QMC is only modestly better than MC with or without randomization for d = 10 to d = 20. The fundamental idea of Junk is to invent a product measure by sorting one variable & randomizing the others. Junk's idea is based on an explicit calculation of the so-called discrepancy of the QMC samples. The product measure refers to the joint measure of the drift & diffusion terms in the Ito stochastic differential equation. We need drift & diffusion to be statistically independent, which means that we want a product measure, which naive QMC does not provide, and which randomized QMC provides with poor discrepancy. Junk & Venkiteswaran have used this idea to solve the Fokker-Planck equation in high dimensions (d = 10 to 20) with excellent results that are vastly superior to boring old MC sampling.

6236-18, Session 3

IMM-based algorithms for target tracking with unknown ballistic coefficient

Z. Zhao, H. Chen, Univ. of New Orleans; G. Chen, C. Kwan, Intelligent Automation Inc.; X. Li, Univ. of New Orleans

Ballistic target tracking using radar measurements in polar or spherical coordinates has attracted much attention of researchers due to the challenge of its inherent nonlinearities in both the target motion model and the radar observation model. Various nonlinear filters have been studied. Most of the research assumed, however, that the target ballistic coefficient was deterministic and perfectly known to the tracking filter, which may not be realistic in practice. In this paper, the ballistic coefficient is assumed to be time invariant, but is random and unknown. We propose and compare four different IMM-based algorithms for ballistic target tracking with fixed, but unknown and random ballistic coefficient. Each algorithm employs the different filter techniques, namely, extended Kalman filter (EKF), unscented filter (UF), particle filter (PF), and linear minimum mean square error filter (LMMSEF). The multiple-model set is designed under the assumption of the ballistic coefficient with the uniform distribution. The pros and cons of each algorithm are summarized. The performance differences are revealed through extensive simulations. The preferred method for the problem of being studied is concluded.

6236-19, Session 3

Nonlinear tracking evaluation using absolute and relative metrics

E. P. Blasch, A. C. Rice, Air Force Research Lab.

Recent computer advances have enabled more computational complex tracking algorithms to be operational viable. Nonlinear algorithms, such as the extended-Kalman filter (EKF) and the unscented Kalman filter (UKF), afford dynamic tracking; however, they assume a Gaussian noise. The Particle Filter (PF) enables non-Gaussian tracking techniques that have unique properties to accomplish urban warfare target tracking. As the new algorithms are being developed, it is also prudent to adapt evaluation techniques that assess the tracker quality. The standard tracking metric is the position root mean square (RMS). The position-RMS is a system level metric that is sensitive to the tracker algorithm, the sensor, and the measurement quality. To isolate the tracker performance we need relative metrics, versus the standard absolute metric of RMS. In this paper, we present an intersection of two contemporary issues for relative nonlinear tracking evaluation including the novel nonlinear track quality metrics and use of metrics to detect sensor bias and model mismatch.

6236-20, Session 3

Radar measurement noise variance estimation with targets of opportunity

R. W. Osborne III, Y. Bar-Shalom, Univ. of Connecticut

A number of methods exist to track a target's uncertain motion through space using inherently inaccurate sensor measurements. A powerful method of adaptive estimation is the interacting multiple model (IMM) estimator. In order to carry out state estimation from the noisy measurements of a sensor, however, the filter should have knowledge of the statistical characteristics of the noise associated with that sensor. The statistical characteristics (accuracies) of real sensors, however, are not always available, in particular for legacy sensors. This paper presents a method of determining the measurement noise variances of a sensor by using multiple IMM estimators while tracking targets whose motion is not known — targets of opportunity. Combining techniques outlined in [YBS01] and [Gauv84], the likelihood functions are obtained for a number of IMM estimators, each with different assumptions on the measurement noise variances. Then a search is carried out to bracket the variances of the sensor measurement noises. The end result consists of estimates of the measurement noise variances of the sensor in question.

6236-21, Session 3

Optimal path planning for video-guided smart munition via multitarget tracking

J. R. Vasquez, J. M. Borkowski, Air Force Institute of Technology

An advent in the development of smart munitions entails autonomously modifying target selection during flight in order to maximize the value of the target being destroyed. A unique guidance law can be constructed that exploits both attribute and kinematic data obtained from an onboard video sensor. An optimal path planning algorithm has been developed with the goals of obstacle avoidance and maximizing the value of the target impacted by the munition. Target identification and classification provides a basis for target value which is used in conjunction with multi-target tracks to determine an optimal waypoint for the munition. A dynamically feasible trajectory is computed to provide constraints on the waypoint selection. Results demonstrate the ability of the autonomous system to adapt to pop up targets, avoid moving obstacles, and revise target selection in flight.

6236-22, Session 4

Improving the passive sonar picture through reverse time tracking

G. R. Mellema, Defense R&D Canada (Canada)

Passive sonar depends on signals of opportunity to detect, track and localize targets. These signals, typically from the target itself, are often very weak relative to the ambient sound, making them difficult to detect and track, and resulting in a sonar picture cluttered with many intermittent track segments.

The position, course and speed of a target can be estimated from its track, but their accuracy depends on the characteristics, including duration, of the available track. In early paper-based sonar systems, where operators detected signals visually and tracked them manually, the time at which a signal was detected was ambiguous, since the operators searched for repetitive events and visually followed them as far backward as possible.

In a modern tracking system using an m out of n detector, the arrival of the mth event is considered the time of detection. A tracker is initiated at this time and updated as new data is acquired. Data prior to the detection is discarded and localization is delayed until sufficient post-detection data has been acquired to produce a suitable track, often tens of minutes.

Initiating a second tracker in reverse time at the time of detection can reduce the amount of time required before a localization estimate is available. Since tracking is more robust than detection, the reverse tracker can glean additional track information from the acoustic data acquired prior to the time of detection and often prior to the data that triggered the detection.

Implementing reverse-time tracking requires a large data cache and significant processing power as well as data association to fuse sequential and/or concurrent forward and reverse time tracks, but it can be an effective tool to rapidly extract additional information from narrowband passive sonar data.

6236-23, Session 4

PHD filters of second order in target number

R. P. Mahler, Lockheed Martin Corp.

The probability hypothesis (PHD) filter is a first-order approximation of the multitarget Bayes filter. Instead of recursively propagating the multitarget posterior density function, it propagates its first-order multitarget moment. This moment, the PHD, is a non-probability density on single-target state space. Since the integral of the PHD is the expected number of targets, the PHD filter also inherently propagates the first moment of the target-number probability distribution (TNPD). During a presentation at the 2005 International Conference on Information Fusion, Prof. Peter Willett suggested that the PHD filter's target-number estimate would be more stable if one could devise a version that also propagated a second-order moment of the TNPD. In another paper at SPIE D&SS we establish a theoretical foundation for such filters, the "cardinalized PHD" (CPHD) filter, which propagates both the PHD and the TNPD. The CPHD filter can accommodate more general false alarm models than the usual PHD filter. In this paper we use the CPHD filter as a basis for approximate PHD filters that propagate the variance as well as the expected value of target number. The primary problem is identifying a parametrized family of distributions which play the same role for discrete probability that Gaussian distributions play for continuous probability. The family of binomial distributions is one such candidate.

6236-24, Session 4

Robust feature-aided association

P. F. Singer, Raytheon Co.

The objective of feature aided association is to reduce the probability of association errors. To this end, the recent association history is used in making the current decision. However, even with the use of features, the association error probability will not be reduced to zero. Consequently, the feature aided decision process must be designed to perform well in the presence of these errors, that is, robust procedures are required.

It recently has been shown that non-parametric tests provide better performance than parametric tests in a feature aided tracking context. Non-parametric tests are typically based upon the order statistics of the data, which in the case of feature aided association, is the recent history of the feature data. The non-parametric test upon which the aforementioned results are based used the order statistics of the maximum. This order statistic can be sufficiently affected by the presence of errors in the recent history of the features to cause association errors. Since the objective of feature aided association is to reduce these errors, robust non-parametric tests are needed.

This paper considers the performance of non-parametric tests similar to the foregoing except they are based upon ranks that are less than the maximum. The performance of each of these tests is examined in the presence of several association error probabilities in order to discern the relationship between the association error probability and the best rank to use for the test statistic.

6236-25, Session 4

Multiple target tracking with possibly unresolved radar measurements

S. Mori, C. Chong, BAE Systems Advanced Information Technologies

It can be shown that sufficient statistics maintained by a multiple-hypothesis algorithm for a multiple tracking problem are expressed as a set of posterior Janossy measures. Based on this fact, a new class of multiple target tracking algorithms were developed ([1-2]), using the posterior Janossy measure density functions, thereby avoiding explicit generation and evaluation of data-to-data association hypotheses. In particular, a method for processing possibly merged or split measurements was derived ([1-2]) using a distributed processing technique applied for a particular information flow pattern, in which possibly merged or split measurements are translated into a set of posterior Janossy measure density functions defined on the target state space. In this paper, we will show another set of algorithms using a mathematical model that expresses possibly merged radar measurements in terms of posterior Janossy measure density functions defined on the measurement space instead of the target state space. The result is a standard nonlinear filtering process in which the posterior probability distribution on the joint multiple target state is maintained and recursively updated using a sum-of-Gaussian expression of a set of posterior Janossy measure density functions. A simple example will be shown.

[1] S. Mori, and C.-Y. Chong, "Multiple Target Tracking Using Janossy

Measure Density Functions," Proc. SPIE Symposium on Signal and Data Processing for Small Targets, San Diego, August, 2005.

[2] S. Mori, and C.-Y. Chong, "Multiple Target Tracking Using Possibly Merged Measurements: Use of Non-Poisson Point-Process Model," Proc. 8th International Conference on Information Fusion, Philadelphia, PA, July 2005.

6236-26, Session 4

Fixed-lag sequential Monte Carlo data association

M. Briers, QinetiQ Ltd. (United Kingdom) and Univ. of Cambridge (United Kingdom); A. Doucet, The Univ. of British Columbia (Canada); S. Maskell, QinetiQ Ltd. (United Kingdom)

There are a number of multiple target tracking algorithms that use multiple scans of data to improve ones ability to successfully solve the data association problem. These tracking algorithms include the Multi-Frame Assignment (MFA) algorithm and the Probabilistic Multiple Hypothesis Tracker (PMHT). In this paper we introduce a novel data association algorithm that uses multiple scans of data to improve the stochastic approximation, and thus the data association ability, of a multiple target Sequential Monte Carlo based tracking system. Such an improvement is achieved by resimulating sampled variates over a fixed-lag time window by artificially extending the space of target distribution. In doing so, the stochastic approximation is improved and so the data association ambiguity is more readily resolved.

6236-27, Session 4

Joint detection and tracking of unresolved targets with a joint-bin processing monopulse radar

N. Nandakumaran, A. Sinha, T. Kirubarajan, McMaster Univ. (Canada)

Detection and estimation of multiple unresolved targets with a monopulse radar is limited by the availability of information in monopulse signals. The maximum possible number of targets that can be extracted from the monopulse signals of a single bin is two. Recently two approaches have been proposed in the literature to overcome this limitation. The first is the joint bin processing that exploits target spill-over between adjacent cells by modeling the target returns in adjacent cells. In addition to making use of the additional information available in target spill-over, it handles a more practical problem where the usual assumption of ideal sampling is relaxed. The second is to make use of tracking information in detection through joint detection and tracking with the help of Monte-Carlo integration of a particle filter. It was shown that more target extraction is possible with tracking information. In this paper, a method is proposed to combine these two approaches, so that one could utilize both target spill-over and tracking information in detection. It increases the detection ability as well as tracking accuracy. Simulation studies are carried out with amplitude comparison monopulse radar for unresolved target scenario. The comparisons of performances of various methods are also provided.

6236-28, Session 4

Complexity reduction in MHT/MFA tracking, part II: hierarchical implementation and simulation results

A. B. Poore, B. J. Slocumb, Numerica Corp.

The MHT/MFA approach to tracking has been shown to have

significant advantages compared to single frame methods. This is especially the case for dense scenarios where there are many targets and/or significant clutter. However, the data association problem for such scenarios can become computationally prohibitive. To make the problem manageable, one needs effective complexity reduction methods to reduce the number of possible associations that the data association algorithm must consider. At the 2005 SPIE conference, Part I of this paper was presented wherein a number of "gating algorithms" used for complexity reduction were derived. These included bin gates, coarse pair and triple gates, and multiframe gates. In this Part II paper, we will provide new results that include additional gating methods, describe a hierarchical framework for the integration of gates, and show simulation results that demonstrate a greater than 90% effectiveness at removing clutter from the tracking problem.

6236-29, Session 4

A modified Murty algorithm for multiple hypothesis tracking

Z. J. Ding, D. Vandervies, Raytheon Canada Ltd. (Canada)

In a modern target tracking system, the measurement-to-track association is typically solved by using assignment algorithms. When a single assignment is used, only the best hypothesis will be generated. The tracker using the best hypothesis is a global nearest neighbor (GNN) tracker. To enhance the track's performance, multiple hypotheses should be maintained, which result in a multiple hypothesis tracker (MHT). Due to the increasing computation and memory of an optimal MHT, a sub-optimal MHT using only the best N hypotheses makes the MHT approach more feasible, yet without sacrificing much of its performance.

In this study, we present two practical modifications of the original Murty algorithm. First, the algorithm is modified to handle rectangular association matrix. The original Murty algorithm was developed for a square matrix. It is found that the expanding rules should be changed so that the crossover pair within an assignment can be extended to the last column and can be repeated for the last column upon certain conditions. The other modification is the allowance of an "infeasible" assignment, where some tracks are not assigned with any measurements, therefore, good "infeasible" hypotheses are maintained and clutter seduced hypotheses are suppressed when the information evidence becomes stronger. Examples are used to demonstrate the modifications of the existing Murty algorithm for a practical implementation of an N-best Multiple Hypothesis Tracker.

6236-30, Session 5

Multitarget-multisensor management for decentralized ad-hoc sensor networks

R. Tharmarasa, T. Kirubarajan, McMaster Univ. (Canada); M. L. Hernandez, QinetiQ Ltd. (United Kingdom); A. Sinha, McMaster Univ. (Canada)

In this paper, we consider the problem of sensor resource management in decentralized tracking systems. Due to the availability of cheap sensors, it is possible to use a large number of sensors and a few local fusion centers (LFCs) to monitor a large surveillance region. Even though a large number of sensors are available, due to frequency, power and other physical limitations, only a few of them can be active at any one time. The problem is then to select the sensor subset that should be used by each LFC at each sampling time in order to optimize the tracking performance under the given constraints. In a recent paper, we proposed an algorithm to handle the above issues for joint detection and tracking, without using simplistic clustering techniques. However, in that paper, a hierarchical architecture with feedback at every sampling time was considered, and the sensor management was performed only at a central fusion center (CFC). However, in general, it is not possible to communicate with the CFC at every sampling time, and therefore performing the sensor management only at the CFC is not viable in most networks. In this paper, we consider an architecture in which there is no CFC, each LFC communicates only with the neighboring LFCs, and communications are restricted. In this case, each LFC has to decide which sensors are to be used and when to communicate with the neighboring LFCs. The main challenges are in getting optimal performance by avoiding simple (target or geographic

location based) clustering techniques and reducing redundancy by avoiding situations in which particular sensors are utilized at more than one LFC.

We propose an efficient algorithm to handle the above problem in real time. Simulation results illustrating the performance of the proposed algorithm are also presented.

6236-31, Session 5

Distributed multiple sensor tracking with the PMHT

D. T. Dunham, Vectraxx

The Probabilistic Multi-Hypothesis Tracker (PMHT) is an emerging algorithm that has shown some success and is intriguing because of its elegance and extensibility in many different aspects. It is a tracking algorithm that offers an alternative to the Multiple Hypothesis Tracker (MHT) in the multiple-frame tracking arena. Instead of enumerating many of the possibilities of track-to-measurement assignments, the PMHT uses a probabilistic approach to assign the likely "weight" of each measurement to contribute to each track. This paper presents the ongoing results of research using the PMHT algorithm as a network-level composite tracker on distributed platforms. In addition, the methods necessary to implement the PMHT in a realistic simulation are discussed. It further describes the techniques that have been tried to ensure a single integrated air picture (SIAP) across the platforms.

6236-32, Session 5

Improved trajectory tracking and launch point determination for ballistic missile defense

R. G. Hutchins, P. E. Pace, Naval Postgraduate School

Detecting and localizing a threat ballistic missile as quickly and accurately as possible are key ingredients to engaging the missile during boost phase over the territory of the aggressor, and rapid and accurate launch point determination is crucial to attack key faculities in a timely fashion. Key sensor ingredients may include bearing-only sensors to detect initial missile launch, followed by hand-off to active, 3-D sensor platforms for tracking and prediction for missile engagement. Earlier research has focused on track initiation, boost phase tracking and rapid launch point determination using augmented IMM and Kalman-based techniques with combinations of bearing-only and range-bearing sensors. This work extends that earlier work by comparing these IMM and Kalman-based trackers and backfitters with the newer particle filters to see what advantages particle filters might offer in this application. Comparisons are being studied using alternative sensor suites and sensor combinations, including passive, bearing-only sensors, range-bearing sensors, and range-range-rate-bearing sensors. Of particular interest are the speed and number of measurements required to obtain a trajectory accuracy suitable for accurate interceptor launch. Simulations used in this research assume a ballistic missile launch point in North Korea targeted at San Francisco.

6236-33, Session 5

Comparison of tracklet methods with deterministic dynamics and false signals

O. E. Drummond, CyberRnD, Inc.

Track fusion filtering is complicated because the estimation errors of a local track and a fusion track the same target might be cross-correlated. If this cross-correlation of these errors does exist, it should be taken into account when designing the filter used to combine the track data. An approach to dealing with this cross-correlation is to use tracklets. One of the important issues in tracklet fusion performance is whether there is filter process noise to accommodate target maneuvers. A number of different tracklet methods have been designed. This paper presents a comparison a tracklets-from-tracks approach to a tracklets-from-measurements approach. Tracklet fusion performance is also compared to measurement fusion filter performance. The emphasis is on performance with targets that exhibit deterministic dynamics and with the possibility of measurements caused by false signals.

6236-34, Session 5

Collaborative sensor management for multitarget tracking using decentralized Markov decision processes

D. Akselrod, McMaster Univ. (Canada); C. Goldman, Univ. of Haifa (Israel); A. Sinha, T. Kirubarajan, McMaster Univ. (Canada)

In this paper, we consider the problem of collaborative sensor management with particular application to using unmanned aerial vehicles (UAVs) for multitarget tracking. We study the problem of decentralized cooperative control of a group of UAVs carrying out surveillance over a region which includes a number of moving targets. The objective is to maximize the information obtained and to track as many targets as possible with the maximum possible accuracy. Limited communication between UAVs and uncertainty in the information obtained by each UAV regarding the location of the ground targets are addressed in the problem formulation. In order to handle these issues, the problem is presented as a decentralized operation of a group of decision-makers lacking full observability of the global state of the system. Recent advances in solving special classes of decentralized Markov Decision Processes (Dec-MDPs) are incorporated into the solution. In these classes of Dec-MDPs, the agents' transitions and observations are independent. Also, the collaborating agents share common goals or objectives.

Given the Dec-MDP model, a local policy of actions for a single agent (UAV) is given by a mapping from a current partial view of a global state observed by an agent to actions. The available probability model regarding possible and confirmed locations of the targets is considered in the computations of the UAVs' policies. Solving optimally Dec-MDPs is known to be computationally very hard.

Therefore, we compare the performance of practical and approximate algorithms. These are built upon approaches taken to solve Dec-MDPs under specific conditions, adapted to our problem. Simulation results are presented on a representative multisensor-multitarget tracking problem.

6236-35, Session 5

A hierarchical benchmark association problem

J. A. Areta, Y. Bar-Shalom, Univ. of Connecticut; M. Levedahl, Raytheon Co.

This paper formulates a benchmark data association problem in a missile defense surveillance problem. The specific problem considered deals with set of sources that provide "event" (track) estimates via a number of communication networks to a Fusion Center (FC) which has to perform data association prior to fusion. A particular feature of the network model is that the information to distinguish among reports from the same source transmitted through different networks is not available at the FC.

The resulting data, organized into sensor lists, is associated using a likelihood based cost function with one of the several existing multidimensional assignment (MDA) methods.The tracks obtained after association are fused using a Maximum Likelihood approach. An additional complication is that false reports can be also transmitted by the sources. Examples with several launches, sources and networks are presented to illustrate the proposed solution and compare the performances of two assignment algorithms -the Lagrangean relaxation based S-D and the sequential m-best 2-D - on this realistic problem. The latter showing promisely trade off between computational complexity and solution quality.

6236-36, Session 5

Advances in multisensor tracker performance modeling

S. P. Coraluppi, NATO Undersea Research Ctr. (Italy)

Over the past several years, the NATO Undersea Research Centre has investigated multi-sensor tracking as part of its research into multistatic active sonar. Our analysis of tracker performance with simulated and sea trial data leads has identified the following key points:

1. Target tracking significantly improves the detection and localization performance of contact data; as such, it provides significant value added to the surveillance processing chain.

2. With high detection redundancy and low FAR data, centralized and distributed multi-sensor tracking both outperform single-sensor tracking, and achieve comparable performance.

3. As detection redundancy is lost and targets exhibit fading behavior (i.e. long detection/no-detection streaks), with low FAR data, distributed tracking outperforms centralized tracking. Indeed, the distributed tracker more effectively exploits single-sensor detection streaks.

4. With high detection redundancy but high FAR data, centralized tracking outperforms distributed tracking. The centralized tracker maintains track more effectively due to a higher input data rate as compared with single-sensor trackers in the distributed architecture. The high data rate leads to smaller data association gates, which is crucial in high FAR environments.

5. In distributed tracking, we achieve better performance by applying CFAR detection across source-receiver pairs, rather than by using the same detection threshold that corresponds to significantly different ROC-curve operating points across source-receiver pairs.

This paper develops a multi-stage tracker performance model that accounts for fading target detection. Model-based performance results are consistent with the simulation-based and sea trial based findings summarized above.

6236-37, Session 6

Track management in a multisensor MHT for targets with aspect-dependent SNR

W. R. Blanding, Univ. of Connecticut; S. P. Coraluppi, NATO Undersea Research Ctr. (Italy); P. K. Willett, Univ. of Connecticut

There are many track initiation and termination strategies, but most amount to one of “k-of-n” detections, cetainly in performance if not in precise form. Such approaches are the bread and butter of MHT track management.

Sonar targets (and possibly others as well) present different SNRs when viewed from different angles. The corresponding aspect dependence might amount to a target’s being easy to see from a narrow range of angles close to broadside (or when the bistatic angle is broadside) but virtually invisible at endfire. Note that targets persist in such states for several pings of data.

Consider further a multistatic situation. An attempted k-out-of-n track initiation stragety based on centralized data is often doomed, since while one bistatic pair may see the target clearly the other “blind” one may force a track-test to fail. (Droopping a track based on such logic is a poor idea as well.) In fact, Coraluppi has recently shown, in his FUSION 2005 paper that applies a clever HMM on target detectability, that centralized tracking is actually worse than distributed.

Clearly this ought not to be. In this paper we address the improvement of the usual k-out-of-n strategy to multisensor sonar MHT tracking.

6236-38, Session 6

Sparse adaptive grids for nonlinear filters

F. E. Daum, Raytheon Co.

We describe a new algorithm for nonlinear filters, which exploits both smoothness and sparseness to reduce computational complexity. Our algorithm is based on recent advances in the numerical solution of partial differential equations. In particular, we apply a new adaptive method for solving the Fokker-Planck equation, which is the fundamental PDE in nonlinear filtering. This adaptive algorithm was invented by Mike Griebel and his co-workers at Bonn University, and it has been successfully applied to a variety of practical problems, including the Fokker-Planck equation. In general the nonlinear filtering problem suffers from the curse of dimensionality. It has been asserted that particle filters beat the curse of dimensionality, but this is incorrect in general. The success of particle filters for high dimensional problems depends crucially on having a good proposal density. Otherwise, the particle filter does not avoid the curse of dimensionality. Moreover, particle filters do no explicitly exploit the smoothness of nonlinear filtering problems, whereas the new method described here explicitly exploits both smoothness and sparseness.

The computational complexity of nonlinear filtering problems depends on: dimensionality of the state vector to be estimated, sparseness, smoothness, ill-conditioning and the shape of the conditional density (e.g., unimodal vs. multimodal), as well as the desired accuracy. A simple back-of-the-envelope formula provides insight into the relationship between these factors for smooth problems. There is an interesting relationship with quasi-Monte Carlo methods that will be described.

6236-39, Session 6

On target track covariance consistency

O. E. Drummond, CyberRnD, Inc.; A. J. Perrella, Jr., Institute for Defense Analyses; S. Waugh, Missile Defense Agency

The primary components of a target track are the estimated state vector and its error variance-covariance matrix (or simply the covariance). The estimated state indicates the location and motion of the target. The track covariance should indicate the uncertainty or inaccuracy of the state estimate. The covariance is computed by the track processor and may or may not realistically indicate the inaccuracy of the state estimate. Covariance Consistency is the property that the computed covariance of a track realistically represents the covariance of the actual errors of the estimated target state. The computed covariance is used in the computations of the data association processing function, consequently, degraded track consistency causes misassociations (correlation errors) that can substantially degrade track performance. The computed covariance is also used by downstream functions, such as the various network-level resource management functions, to indicate the accuracy of the target state estimate. Hence, degraded track consistency can mislead those functions and the war fighter about how accurate each target track is.

Far more attention has been given to improving the accuracy of the estimated target state than in improving the track covariance consistency. This paper addresses the importance and analyzes properties of covariance consistency. The feasibility and typical performance of some simple methods for improving covariance consistency are explored.

6236-40, Session 6

On adaptive phased-array tracking in the presence of main-lobe jammer suppression

W. Koch, FGAN-FHR (Germany)

The accuracy of sensor models in tracking algorithms is critical to ensure good tracker performance. Recent advances have been made in characterizing the angle measurement covariance for phased array monopulse radar systems when adaptive array processing is used to null out a jammer source. These advances provide the opportunity to use improved sensor models in tracking. Using a more realistic adaptive phased array

monopulse radar simulation, five tracking systems are compared when used to track a maneuvering target passing into and through jammer interference: an Extended Kalman Filter (EKF) with fixed measurement covariance, an EKF with corrected measurement covariance, an EKF that uses pseudo-bearing measurements when the target is hidden in the jammer interference (using either fixed or corrected measurement covariance), and a Gaussian Sum Filter that incorporates the sensor response to both the jammer and beam pointing errors. Each tracking system differs in how closely it replicates sensor performance. We show that tracking algorithms that do not use both the "negative" contact information when the target is inside the jammer interference and corrected angle measurement covariance are unable to reacquire the target when it exits the jammer interference. Further, we show that the performance of the pseudo-bearing EKF is equal to or better and requires far less processing power than the Gaussian sum filter using a more complex sensor model. This might be a consequence of certain ad hoc approximations used.

6236-41, Session 6

Nonlinear least-squares estimation for sensor and navigation biases

S. M. Herman, A. B. Poore, Numerica Corp.

Fusion of data from multiple sensors can be hindered by systematic errors known as biases. Specifically, the presence of biases can lead to data misassociation and redundant tracks. Fortunately, if estimates of the unknown biases can be obtained, the measurements from each sensor can be debiased prior to fusion. In this paper, we present an algorithm that uses truth data for offline estimation of time invariant biases. Our approach is unique for two reasons. First, we explicitly avoid the use of fictitious "roll-up" biases and instead attempt to model the true sources of systematic errors. This leads to a highly nonlinear bias model that contains 18 unknown parameters. Second, we use the singular value decomposition (SVD) within our nonlinear least-squares estimator to automatically handle the issue of parameter observability. We also show how the SVD can be used for differentiating between absolute and relative bias estimates. Finally, we demonstrate that our algorithm can improve track accuracy, especially for mobile sensor platforms.

6236-42, Session 6

Estimating the DOA and SNR of separating targets

L. M. Ehrman, Georgia Institute of Technology; W. D. Blair, Georgia Tech Research Institute; P. K. Willett, Univ. of Connecticut

Many multi-target tracking problems involve targets that are closely-spaced and/or separating. In such cases, high-fidelity tracking mandates that tracks be initiated as soon as possible after separation events and maintained separately even if targets move back into the same radar range bin, making them unresolved in the usual radar sense of the term. Prior work has demonstrated that the joint multiple bin processing algorithm can localize returns from otherwise unresolved targets and even estimate target power. This paper explores the improvement that is possible using this algorithm. Waveform requirements are analyzed, as are two methods for implementing a hidden Markov model (HMM) to estimate the number of targets present in a given dwell.

Although the algorithms investigated in this paper could be applied to a number of tracking problems, the results in this paper are derived from a high fidelity radar simulation for ballistic missile defense. When used with an appropriate waveform, the joint multiple bin processing algorithm allows for faster track initiation on separating targets and better overall track completeness.

6236-43, Session 6

The probability hypothesis density filter in detection of target spawn

P. K. Willett, Y. Bar-Shalom, O. Erdinc, Univ. of Connecticut

Multiple target tracking techniques require data association that operates in conjunction with filtering. When multiple targets are closely spaced, the conventional approach (MHT/assignment) may not give satisfactory results, mainly due to the diffculty in deciding the number of targets. Recently, the first moment of the "multi-target posterior density", called the probability hypothesis density (PHD), has been proposed to address the multi-target tracking problem. Particle filtering techniques have been applied to implement the PHD based tracking.

In this paper, we explain our interpretation of the PHD, then investigate its performance on the problem of tracking unresolved targets from multiple sensors. Simulation results for two-dimensional scenario are given to show the performance of the approach. We incorporate Mahler's newest PHD results that improve the quality of the object-number estimates. We also demonstrate the importance of ancillary track-labeling (some external data association) when new targets are spawning.

6236-44, Session 6

Joint IMM/MHT tracking and identification with confusers

J. A. Lancaster, S. S. Blackman, E. T. Taniguchi, Raytheon Space and Airborne Systems

It is widely accepted that Classification Aided Tracking (CAT) has the potential to maintain continuous tracks on important targets. Moreover, when augmented with target behavior, a joint tracking and ID system can enhance the data association process for ground tracking systems. It is also recognized that it is likely that some targets in any scenario may not be included in a database, and the presence of such confusers would diminish both tracking and ID performance. Thus, this paper presents a joint tracking and identification architecture that has been developed which addresses the issue of confusers. This approach augments the Dempster-Shafer mass vector to include the hypothesis that the target type is not in the database. These methods are being tested using simulated dynamic ground targets and radar High Range Resolution (HRR) data provided by the Moving and Stationary Target Acquisition and Recognition (MSTAR) project.

6236-46, Poster Session

Demonstration of a 5.12-GHz optoelectronics sampling circuit for analog-to-digital converters

C. Villa, E. J. Donkor, P. D. Kumavor, Univ. of Connecticut

The development of high-speed analog-to-digital converters (ADCs) has led to the realization of systems that perform real time signal processing functions. The sampling speed and timing jitter of the sampler circuit limits the analog signals bandwidths. One way of circumventing this limitation is to use optical techniques since they provide high repetition rate (GHz) and short pulse (fs) signals.

In this paper, we present an optoelectronic sampling circuit for an optical ADC with an aggregate of 5.12 Gigasample/s and a time jitter of 80 fs. The RF signal to be sampled is connected to 8 sampling circuit in parallel. Each sampling channel consists of a reverse-biased photodiode that acts as a fast optoelectronic switch in series with a load resistor. A bias tee was used to couple the RF signal to be sampled, and the d.c. voltage to reverse bias the photodiodes. The DC offset RF signals was then connected to each channel and was sampled by actuating the photodiodes with a modelocked optical pulses having repetition rate of 640MHz. A relative delay of 0.195 ns was set between the sampling clocks. Thus the sampling circuits sampled different phases of the RF. The outputs of the eight sampling circuits were multiplexed together to give an aggregate

sampling rate of 5.12GSPS. A biasing voltage applied to the photodiodes provided two advantages over the back-to-back diode switching configuration: Firstly, it enabled only one photodiode per channel, thus reducing the number of components in the circuit. Secondly, the optical power required to close the switch was halved. Finally, a synchronizer trigger circuits was designed in order that all eight sampling circuits can be triggered for simultaneous measurement.

6236-49, Poster Session

Nonlinear estimation techniques for impact point prediction of ballistic targets

D. F. Hardiman, U.S. Army Research, Development and Engineering Command

This paper considers three nonlinear estimation algorithms for impact point prediction of ballistic targets. The paper assumes measurements are available from a 3D surveillance radar or phased array radar over some portion of the ballistic trajectory. The ballistic target (BT) is tracked using an extended Kalman filter (EKF), an unscented Kalman filter (UKF), and a particle filter (PF). With the track estimate as an initial condition, the equations of motion for the BT are integrated to obtain a prediction of the impact point. This paper compares the performance of the three filters (EKF, UKF, and PF) for impact point prediction.

The traditional Extended Kalman Filter takes nonlinear measurements and linearizes them to form a linear model of the system. Therefore, direct processing of nonlinear systems in an Extended Kalman Filter is limited by strict initial assumptions. Both the Unscented Kalman Filter and the Particle Filter allow nonlinear systems to be modeled without prior linearization. The primary focus of the research presented in this paper is comparing the performance and accuracy of the Extended Kalman Filter (EKF), the Unscented Kalman Filter (UKF), and the Particle Filter (PF) for impact point prediction. As part of this research, several different types of proposals to the Particle Filter will be considered. Simulation is used to compare these different estimation techniques.

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6237-01, Session 1

SAR challenges for urban environments

R. L. Williams, Air Force Research Lab.

Abstract not available

6237-02, Session 1

Urban scene analysis from SAR image sequences

D. Blacknell, R. D. Hill, C. P. Moate, QinetiQ Ltd. (United Kingdom)

The nature of many modern military operations increasingly requires them to be performed in urban or semi-urban environments. Airborne synthetic aperture radar (SAR) provides a 24 hour, all weather capability to obtain data to support these tasks from long standoff ranges. The complex structures present in urban scenes produce a variety of radar phenomena such as layover, shadowing and occultation that make exploitation of the data a difficult task. However, the use of a number of different radar modes, such as spotlighting to provide image sequences and the use interferometric imaging, captures a large amount of information that can be used to address this task. The problem lies in combining the information to provide the best analysis of the structures that make up the scene. This paper describes a technique for extracting building dimensions by combining information from shadows and building returns observed in image sequences together with interferometric information. Buildings are characterised by simple wire-frame models parameterised by the building dimensions. The forward problem is solved to anticipate the appearance of the building in all the gathered imagery and this is embedded within an iterative search through parameter space, using an active contour methodology, to find the best fit to the data. In this way, the inverse problem of inferring the real-world structure that gave rise to the observed data is solved. Results of the application of this technique to real SAR data will be presented.

6237-03, Session 1

Building recognition from multi-aspect high-resolution interferometric SAR data in urban areas

A. Thiele, U. Thoennessen, U. Soergel, FGAN-FOM (Germany)

The improved ground resolution of state-of-the-art synthetic aperture radar (SAR) sensors suggests utilizing this technique for the analysis of urban areas. However, building reconstruction from SAR or InSAR data suffers from the consequences of the inherent oblique scene illumination, such as layover, occlusion by radar shadow, and multipath signal propagation. Especially in built-up areas, building reconstruction is therefore often impossible from a single SAR or InSAR measurement alone. But, the reconstruction quality can be significantly improved by a combined analysis of multi-aspect data.

In this paper an approach for the detection and reconstruction of buildings from multi-aspect high-resolution InSAR data sets is proposed. The analysis is carried out in an iterative manner. Building features are extracted both from the magnitude and in the phase information of the interferometric data. From an initial set of primitive objects building hypotheses are built-up independently in each InSAR data set. After the projection from the slant range into the world coordinate system these independent results are fused. Intermediate results are used as basis for simulations of InSAR data according to the given sensor parameters. The simulation results are compared with the real imagery. Deviations between the simulations and the real data are eliminated step-by-step. The approach is demonstrated for two InSAR data sets of a building group in an urban environment, which have been taken from orthogonal viewing directions. The InSAR data has a spatial resolution of about 30 cm.

6237-04, Session 1

Radar signals dismount data production

U. K. Majumder, M. J. Minardi, E. P. Blasch, Air Force Research Lab.

Recent interest in dismount tracking from non-EO based sources has become important for urban operations. EO / camera imaging is subject to line of site and weather conditions which makes it a non-robust source for dismount tracking. Other sensors exist (e.g. radar) to track dismount targets; however, little radar dismount data exists. This paper examines the capability to generate dismount data sets for radar frequency (RF) processing. We use the PoserTM program to generate 500 facet models of human dismount walking and Xpatch to generate synthetic wideband radar data. The dismount data set provides a forum to investigate moving target exploitation. The paper examines (1) the formation of 3-dimensional RF dismounts imaging data set, (2) post-processing analysis to create 3-dimensional radar images, and (3) applies a standard tracking algorithm to the RF data for moving target exploitation.

6237-05, Session 1

Theoretical radar-Doppler models for pivoting mechanical and biological objects-of-interest

A. K. Mitra, Air Force Research Lab.

An set of approximate theoretical equations for the Doppler response of monostatic radar signals due to slowly pivoting objects are derived. The treatment is based on physical models extracted from the mechanical engineering community. Potential applications inlcude analysis of load-based vehicle classification and detection of biological movements such as human joint rotations. Several example calculations are presented based on the resulting theorectical formulas. These examples include Doppler calculations for notional first-order vehicle suspension models and first-order human joint (arm/leg) rotation models. Each set of example calculations includes two sets of notional radar parameters in order to provide insight into potential Doppler pivot detection capabilties as a function of basic radar parameters such as frequency and PRF.

6237-06, Session 2

Angular description for 3D scattering centers

R. Bhalla, Science Applications International Corp.; A. Raynal, H. Ling, The Univ. of Texas at Austin; J. Moore, Science Applications International Corp.; V. J. Velten, Air Force Research Lab.

It is well known that the electromagnetic scattering from an electrically large target can often be modeled as if it is emanating from a discrete set of scattering centers on the target. A 3D scattering center set is a sparse representation that allows for reconstruction of the 1D range profile and 2D inverse synthetic aperture radar imagery of the target in real time under extended operating conditions. Various techniques have been presented to extract 3D scattering centers for complex targets. For example, a 3D scattering center extraction algorithm based on the shooting and bouncing ray technique was presented in Bhalla and Ling (IEEE Trans. Antennas Propagat., 44, 1996). However, the algorithm is limited to data

in a small angular sector. To fully characterize a target at all aspects, 3D scattering center extractions need to be carried out at various angles on a dense grid in both elevation and azimuth. This results in multiple sets of scattering centers with no correspondence across angles. A previous attempt on scattering center association based on position-only information (Bhalla et al, IEEE Trans. Antennas Propagat., 45, 1997) achieved only limited success. More recently, a 3D geometric invariance theory was formulated to perform feature tracking (Stuff, SPIE 2000). In this paper we present an approach to track 3D scattering centers and model their associated angular and spatial behaviors. Tracking correspondence of 3D scattering centers across angles can provide useful insights into target physics and feature stability. Results for various targets using the algorithm will be presented.

6237-07, Session 2

IFSAR image reconstruction with multiple scattering centers in a resolution cell

C. D. Austin, R. L. Moses, The Ohio State Univ.

Interferometric Synthetic Aperture Radar (IFSAR) is a method of radar imaging used to form three dimensional radar images from synthetic apertures at two closely spaced elevation angles. IFSAR techniques assume that there is one scattering center present in a resolution cell. When this assumption is violated, calculation of pixel height in the offending cell can be highly erroneous. Xpatch backhoe data shows that many resolution cells contain more than one scattering center, suggesting that this assumption may be violated for many pixels in complex targets. We propose a multiple hypothesis detection and estimation approach to reducing the average height error of the pixels displayed in the image when there is only noise or more than one scattering center in a resolution cell. The approach works on a pixel by pixel basis and does not assume local smoothness or incorporate local averaging.

With the aid of experimental evidence from the Xpatch backhoe ground truth data, a model of the scattering behavior is introduced and used to formulate a ternary hypothesis test, testing for zero, one, or more than one scattering center in a resolution cell. The output of the detection algorithm is used to determine if the data should be used to estimate pixel height with an appropriate Maximum Likelihood (ML) scheme or if it should be discarded. The goal of the approach is to correctly detect the number of scattering centers in a resolution cell, and ultimately reduce the number of large height error pixels in the reconstructed image. The effectiveness of this approach on correctly detecting the number of scattering centers and its reduction in mean square error (MSE) height error in the overall image will be evaluated on the Xpatch backhoe data.

This work extends that given in the 2005 Symposium. Previous work investigated an intuitively derived statistic for discriminating between resolution cells with large or small height error when there are two scattering centers in a resolution cell with no noise. Xpatch backhoe data was filtered using the statistic, and performance of the statistic on this set of data was examined qualitatively by showing IFSAR reconstructions of the backhoe before and after filtering. In the approach presented here, a detection-estimation approach is applied to IFSAR image reconstruction. The number of scattering centers in a resolution cell (zero, one, or more than one) in the presence of noise is detected using a ternary hypothesis test and then IFSAR height estimation is performed based on the decision of the detector. Detection statistics are derived with optimal detection as the goal. Performance analysis on Xpatch backhoe data is presented through comparison of the detection-estimation reconstruction and Xpatch backhoe ground truth data; both probability of detection versus false alarm in detecting the number of scattering centers in a resolution cell and MSE height error performance is analyzed.

6237-08, Session 2

Feature extraction algorithm for scene visualization using 3D bistatic SAR

J. A. Jackson, The Ohio State Univ.; B. D. Rigling, Wright State Univ.; R. L. Moses, The Ohio State Univ.

We propose a feature extraction algorithm to detect and characterize scattering centers in 3D using monostatic or bistatic synthetic aperture radar measurements. Attributed scattering models have been developed which describe the radar response of canonical shapes. We build on Rigling's work on attributed scattering models for 3D bistatic SAR [1]. We employ such models to characterize a complex target geometry as a superposition of simpler, low-dimensional structures. Such a characterization provides a means for target visualization. Maximum likelihood estimation of all of the scattering center parameters in a scene becomes computationally burdensome as the number of scattering centers increases. Segmentation into smaller, low-dimensional scattering regions makes the feature extraction computationally tractable [2,3]. Therefore, we segment imagery into regions of high energy and obtain parameter estimates for a canonical model in each region. The estimation problem fits the canonical shape model with parameters, such as size and orientation, which correspond to the measured target response. We present an algorithm to estimate model parameters for canonical scattering structures. We apply the algorithm to 3D bistatic scattering prediction data of a backhoe and use the extracted features to generate an iconic visualization of the scene. Initial results using the backhoe data set will be shown.

[1]. Rigling, B. and R. Moses, 'GTD-based Scattering Models for Bistatic SAR,' SPIE Algorithms for Synthetic Aperture Radar Imagery XI, Orlando, FL, Apr. 12-16, 2004.

[2]. Koets, M. and R. Moses, 'Image domain feature extraction from synthetic aperture imagery,' 1999 International Conference on Acoustics, Speech, and Signal Processing (ICASSP 1999), Vol. 4, Mar. 15-19, 1999, pp. 2319-2322.

[3]. Akyildiz, Y. and R. Moses, 'A Scattering Center Model for SAR Imagery,' EOS/SAR Symposium on Remote Sensing, Florence, Italy, Sept. 20-24, 1999.

6237-10, Session 2

SAR depth-of-focus: achieving three-dimensional resolution with wide-angle apertures

L. Moore, L. C. Potter, The Ohio State Univ.

Non-planar synthetic apertures have long been recognized as providing three-dimensional (3-D) image formation. In this paper, we present an analysis of 3-D image formation from wide-angle, constant elevation apertures. Explicit expressions are presented for point spread functions in both near-field and far-field scenarios. Fast image formation algorithms are presented for 3-D imaging either from phase history or by post-processing two-dimensional (2-D) imagery. Non-parametric imaging is presented, along with resolution-enhancement via parameter estimation. Finally, we evaluate the role of scattering persistence in wide-angle 3-D image formation.

An analogy can be drawn between depth-of-focus concepts in microscopy and the wide-angle, single elevation angle radar geometry. An observed effect of using back-projection for 2-D SAR imaging is a smeared ring, with arc equal to that of the aperture, representing targets lying outside of the chosen focus plane. Similar rings are observed in microscopy and are referred to as circles-of-confusion. Depth-of-focus in microscopy describes the specified allowable focus error of a target that restricts the size of the circle-of-confusion. For our SAR application, the concept of depth-of-focus is comparable to the resolution in the height, or z resolution of our 3-D image.

6237-11, Session 2

A 6-18 GHz 3D ISAR data collection system

C. J. Beaudoin, A. J. Gatesman, R. H. Giles, J. Waldman, Univ. of Massachusetts/Lowell; W. E. Nixon, U.S. Army National Ground Intelligence

A 6-18 GHz compact radar range has been developed for acquisition of radar signatures of small rockets and projectiles as well as collection of

VHF/UHF signatures of various ground targets using physical scale modeling techniques. The radar range operates in a monostatic, stepped-frequency, and pulsed/CW modality and incorporates an off-axis parabolic reflector serving as a collimating optic. The reflector provides a 2 ft. x 2 ft. planar wavefront to emulate far-field target illumination. The beam size is suitable for measurement of a wide-range of small rockets and projectiles as well as multi-target and foliage penetration scenarios utilizing 1/35th scale targets and dielectrically scaled scenes. An eight axis motorized staging system provides the precise target positioning required for 3-D data collections and interferometric radar processing. It is well known that UHF SAR systems require large integration apertures to achieve adequate image resolution. Precise motion control is utilized to model realistic operational SAR collection scenarios such as the variation in elevation angle as a function of azimuth angle. UHF radar signatures/imagery of tactical targets will be presented along with microwave radar signatures/imagery of projectiles.

6237-12, Session 3

Efficient algorithm for SAR 2D stripmapping

J. Burki, C. F. Barnes, Georgia Institute of Technology

Strip-Mapping is a Synthetic Aperture Radar (SAR) imaging modality capable of producing high-resolution terrain images from data collected by a relatively small airborne or spaceborne antenna. This data collection is done in cross-range or slow-time along flight trajectory and range or fast-time along direction of electromagnetic wave propagation. The slow-time imaging is what distinguishes SAR from its predecessor imaging radars. However, the fast-time imaging, used to supplement the slow-time imaging introduces some visual artifacts into SAR imagery due to the kind of waveform used for high resolution range imaging. In this paper, we introduce the concept of SAR 2-D Stripmapping that extends the slow-time imaging concept to range besides cross-range to rid the SAR imagery of the visual artifacts due to range skew and residual video phase (RVP). We also derive an efficient algorithm for implementation of SAR 2-D Stripmapping.

6237-13, Session 3

System analysis of a short-range SAR repeater

J. A. Montes de Oca, B. D. Rigling, Wright State Univ.

Current wide-area Synthetic Aperture Radar (SAR) system concepts call for a single data collection platform to orbit a large (e.g, 20 km) spot at a nominal range of 40 km. The large standoff distance and desire for fine resolution, coupled with a need for persistent real-time sensing, pose a significant challenge in terms of SNR performance and data processing. Increased SNR and reduced processing load can be achieved by decreasing the range of the SAR system and the size of the area of interest. Employing multiple cooperating SAR systems allows the same overall coverage area to be maintained with a patchwork of SAR footprints. This paper analyzes a high-level system architecture, for multiple SAR systems, that provides uninterrupted coverage over a wide area. System analysis includes range-Doppler resolution, SNR performance and mutual interference issues. Furthermore, we consider the deployment of close-in bistatic receivers to better engage obscured targets and to more quickly collect wide-angle data.

6237-14, Session 3

Joint image formation and anisotropy characterization in wide-angle SAR

K. R. Varshney, Massachusetts Institute of Technology; M. Çetin, Sabanci Univ. (Turkey) and Massachusetts Institute of Technology; J. W. Fisher III, A. S. Willsky, Massachusetts Institute of Technology

We consider the problem of jointly forming images and characterizing anisotropy from wide-angle synthetic aperture radar (SAR) measurements. Conventional SAR image formation techniques assume isotropic scattering, which is not valid with wide-angle apertures. We present a method based on a sparse representation of aspect-dependent scattering with an overcomplete basis composed of basis vectors with varying levels of angular persistence. Solved as an inverse problem, the result is a complex-valued, aspect-dependent response for each spatial location in a scene. Our non-parametric approach does not suffer from reduced cross-range resolution inherent in subaperture methods and considers all point scatterers in a scene jointly. The choice of the overcomplete basis set incorporates prior knowledge of aspect-dependent scattering, but the method is flexible enough to admit solutions that may not match a family of parametric functions. We enforce sparsity through regularization based on the lp norm, $p<1$. This formulation leads to an optimization problem that is solved through robust half-quadratic methods. We also develop a graph-structured interpretation of the overcomplete basis leading towards approximate algorithms using hill-climbing search with appropriate stopping conditions and search heuristics. We present experimental results on synthetic scenes and the backhoe public release dataset.

6237-15, Session 3

A compact low-cost wide-angle radar test bed

J. D. Gorman, SET Corp.; U. K. Majumder, Air Force Research Lab.; R. L. Dilsavor, J. C. Reed, SET Corp.; M. J. Minardi, E. G. Zelnio, Air Force Research Lab.

Recent technology developments in digital radio, low-cost inertial navigation systems and unmanned air vehicle design are converging to enable and make practical several new radar sensing modes such as simultaneous SAR/GMTI from persistent staring-mode radar, 3D SAR from a single-pass, single phase center radar and wide-angle radar tracking of dismounts. One of the challenges for algorithm developers is a lack of high-quality target and clutter signature data from the new radar modes. AFRL's Sensor Directorate and SET Corporation are developing a compact, low-cost wide-angle radar test bed capable of simulating a variety of radar modes, including 3D SAR, SAR/GMTI from staring-mode radar and ultra-fine resolution range-Doppler. We provide an overview of the wide-angle radar test bed architecture, its modular design and our implementation approach. We then describe several non-conventional wide-angle radar sensor modes and outline a corresponding series of test bed data collection experiments that could be used to support the development of new tracking and recognition algorithms.

6237-16, Session 3

A comparison of fully polarimetric x-band ISAR imagery of scaled model tactical targets

T. M. Goyette, J. C. Dickinson, J. Waldman, R. H. Giles, Univ. of Massachusetts/Lowell; W. E. Nixon, U.S. Army National Ground Intelligence Ctr.

With the growing interest in ATR, there is a need for high-resolution fully polarimetric data on tactical targets at all radar bands. The U. S. Army National Ground Intelligence Center (NGIC) and the University of Massachusetts Lowell (UML) have responded to this requirement with the development of compact radar ranges to acquire high-resolution target signature data using scale models of tactical targets. In recent papers the development of a 350GHz compact range for collection of X-band data using 1/35th scale models had been reported, and preliminary results were presented for a single polarization. Construction of the new 350GHz compact range has been completed and is able to collect fully polarimetric scaled X-band radar data with 6-inch full-scale range resolution. NGIC and UML now operate compact ranges from UHF to W-band using 1/16 scale and 1/35th scale. Since the two 1/35th scale ranges can collect UHF and X-band data using the same targets, it is possible to study multi-target scenes at frequencies that are commonly used for target detection and identification. In order to investigate the reproduction of X-band data using scale models, fully polarimetric high-resolution target signature data has been collected on several targets which include a high-fidelity hand

built 1/16th scale T72 and a commercial 1/35th scale T72 modified to match it's features. A correlation study of ISAR images is currently being performed between the X-band data sets collected on these models and X-band data sets taken on a full-scale T72. In this study ISAR images are formed from the data for use in several different target correlation algorithms that have been presented in previous papers. The results of the inter-comparisons of X-band data using full-scale, 1/16th scale, and 1/35th scale will be presented in addition to results for multi-target scenes.

6237-17, Session 3

Implementation and analysis of a fast backprojection algorithm

L. A. Gorham, Air Force Research Lab.

Abstract not available

6237-18, Session 3

Comparison of polar formatting and back-projection algorithms for spotlight-mode SAR image formation

C. V. Jakowatz, Jr., N. E. Doren, Sandia National Labs.

Recently, the convolution/back-projection algorithm (CBP) for SAR image formation has been touted as the "gold standard" for spotlight-mode SAR, and as well-suited for a small form-factor in man-portable or small UAV applications. In this paper we demonstrate that this is far from the truth. In fact, CBP is very inefficient computationally when compared to the Polar Formatting Algorithm (PFA), and in addition produces images that are in no way superior to those formed via PFA. For real-time SAR image formation, we suggest "going off of the gold standard" and instead employing PFA. We demonstrate why this is true via careful image quality and formation time case studies.

6237-19, Session 3

Correction of propagation-induced defocus effects in certain spotlight-mode SAR collections

C. V. Jakowatz, Jr., Sandia National Labs.; S. Schmerwitz, DLR (Germany)

When SAR phase histories are collected at long range and involve the radar looking through an atmosphere with high water vapor contect, certain spatially-variant defocus effects can be present in the formed imagery. In this paper we present data from one such collection and demonstrate how to correct the imagery using spatially varying phase gradient autofocus. A non-parametric phase correction scheme such as PGA is required in this situation as the phase errors have high spatial frequency content and cannot be adequately estimated with traditional low-order parametric algorithms. We then provide confirmation that the effects are indeed atmospherically induced, by showing that the power spectra of the extracted phase error estimates follow closely the turbulence model of Kolmogorov.

6237-20, Session 3

Multistage entropy minimization for SAR image autofocus

B. D. Rigling, Wright State Univ.

This paper discusses a multistage approach to entropy minimization for SAR image autofocus. The new algorithm is compared to existing approaches, including point based autofocus, sub-aperture based autofocus, and hybrid methods. Monte Carlo statistical results are presented for simulated clutter scenes and point target scenes. The new minimum entropy autofocus provides improved speed and accuracy in correcting azimuth phase errors in both scenarios.

6237-21, Session 4

A challenge problem for detection of targets in foliage

M. Lundberg, L. M. Ulander, Swedish Defence Research Agency (Sweden); W. E. Pierson, Jr., Air Force Research Lab.; A. Gustavsson, Swedish Defence Research Agency (Sweden)

A challenge problem helps focus a research community's effort by providing focus and a goal. The problem should be specific enough so as to define a reasonably sized research area but general enough so as not to limit the imagination of the researchers. To accomplish this balance a challenge problem definition includes three components: problem definition, data description, and baseline performance. This paper describes these three components for a challenge problem whose scope is the detection of stationary vehicles in foliage using VHF-band SAR data.

The data for this challenge problem consists of VHF-band SAR images collected by the Swedish CARABAS-II system. Each image contains 25 terrain vehicles deployed in boreal forest. The group of 25 vehicles consists of three different vehicle types. The vehicle types were chosen to provide vehicles of different sizes. The images were collected during four separate flights. Before each flight the targets were redeployed.

CARABAS-II produces SAR images at the low VHF-band (20-85 MHz). At these frequencies targets concealed in a forest are usually visible because of the foliage penetrating capabilities of the sensor. The problem is often not to detect the targets but to reduce the false alarm rate. This requires suppressing the clutter which is dominated by larger tree trunks, buildings and other made-made objects.

The purpose of releasing the CARABAS-II data set is to provide the community with VHF-band SAR data that supports development of new algorithms for robust target detection with low false-alarm risk. The set of images supports single-pass, two-pass and multi-pass target detection.

6237-22, Session 4

Target detection using an improved fractal scheme

D. Charalampidis, G. W. Stein, Univ. of New Orleans

An improved Wavelet-based Fractal (WF) feature scheme is evaluated for synthetic aperture radar (SAR) automatic target recognition (ATR) systems. The technique combines rotational invariant texture analysis with size and intensity measures. Recently, a different fractal-based feature, namely the Extended Fractal (EF) feature, was evaluated for ATR and was shown to have an improved performance over previous approaches. Nevertheless, the WF technique was compared to the EF approach for a general texture classification application and was shown to exhibit superior performance over EF. In this work, the WF scheme is evaluated for ATR and compared to EF and other ATR techniques. We demonstrate the improved performance using the new feature over a database of SAR imagery containing targets and clutter.

6237-23, Session 4

Unified measures of target detection performance

D. R. Parker, S. C. Gustafson, Air Force Institute of Technology; T. D. Ross, Air Force Research Lab.

This research compares the usefulness of alternative performance metrics to those more commonly used in target detection applications. The alternative metrics include the Dice Similarity Coefficient, Mutual Information metric, and the Youden Index. As a comparison, the receiver operating characteristic (ROC) curve is a commonly used metric for quantifying the performance of a target detection system. The ROC curve is a discrimi-

nation metric that measures the ability of a target detection system to distinguish between target and non-target. Another metric is Confidence Error, which quantifies a system's knowledge of its own performance. An approach is developed that makes use of an optimum combination of these metrics. This combination may be dynamically adjusted and updated based on the particular target detection system evaluator's current and future requirements.

6237-24, Session 4

Kernel Wiener filter-based change detection

M. G. Tates, Army Research Lab. and Morgan State Univ.; N. M. Nasrabadi, H. Kwon, Army Research Lab.; C. White, Morgan State Univ.

We propose a Wiener filter based change detection algorithm to overcome some of the limitations of co-registered frame differencing, namely to exploit the highly correlated nature of speckle noise, thereby reducing false alarms. Given two stochastic, jointly wide-sense stationary signals, the Wiener filter can be implemented for prediction of one data set from the other using the auto and cross correlations of the data. By minimizing the variance of the error committed in this prediction, the Wiener filter provides the optimal solution in the least mean squared error sense. If the data are well represented by the 2nd order statistics, the Wiener prediction will be very close to the actual data.

In applying Wiener filter theory to the detection of sudden changes which comprise only a small number of pixels relative to the entire image size, correlation will not adequately model this change. Consequently, there will be low error in the prediction where the images are the same and no change exists between the two and there will be large error in the prediction of pixels where a change has occurred. We apply a threshold to the error from this prediction to develop the change mask. While Wiener filter based change detection will likely reduce false alarms generated by the highly correlated speckle noise and misregistration errors, its linear nature is unlikely to mitigate false alarms which are generated by other nonlinear variations in the two images. These variations may be caused by unknown fluctuations in the amplitude/phase in the radiation pattern of the physical radar between the two data sets and subtle inconsistencies in the data acquisition circuitry.

Therefore, we propose a kernel version of Wiener filter based change detection in SAR imagery by deriving the analogous algorithm in the kernel domain. In order to derive the kernel version of the Wiener filter, we apply a nonlinear mapping to represent the data in a high dimensional feature space in order to exploit higher order correlations in the data. Since it is computationally impractical to explicitly carry out this mapping in the high dimensional space, we must employ the kernel trick in order to express the data in terms of kernel functions. We thereby avoid computations in the higher, possibly infinite domain.

We develop a Wiener based change detection algorithm and derive its analogous kernel form and apply both methods to detect mines in co-registered, geometrically corrected, averaged, multi-look SAR images of the same scene. We present ROC curves to illustrate the enhanced change detection performance achieved by the Wiener filter based change detection methods as compared to simple differencing.

6237-25, Session 4

A new coherent change detection algorithm for FOPEN SAR

L. M. Novak, BAE Systems Advanced Information Technologies

Abstract not available

6237-28, Session 5

Assessment of a novel decision and reject method for multiclass problems in a target classification framework for SAR scenarios

W. Middelmann, A. Ebert, U. Thoennessen, FGAN-FOM (Germany)

The focus of this paper is the development of a decision method and a reject criterion suitable for a kernel-machine-based target classification framework for SAR scenarios.

The proposed processing chain consists of a screening process identifying ROIs with target cues, an object segmentation, and a classifier extended by a reject criterion. A feasible screening method only provides object hypotheses. Therefore the quality of the following classification step significantly depends on the reject criterion reducing the false alarms.

The training methodology is implicated by the special type of classifier, because kernel-machines are two-class classifiers. Therefore, the extension to a multi-class classifier uses a two-stage decision heuristic based on class voting. The results of the basis kernel-classifiers are combined to extend the system to a multi-class classifier. A controllable reject criterion is given in the high dimensional space of the kernel machine. Here an acceptance region is defined by a minimal distance to the decision hyperplanes. In previous investigations this approach was confirmed to be powerful and robust for several data sets.

But in complex scenarios the approach yields unsatisfactory results. To overcome this problem a novel reject methodology was developed. Hereby the result of the multi-class classifier defines the feature vector for a supplementary classifier responsible for accepting or rejecting the objects. Therefore, an object is only accepted if this second classifier is confirming the result of the first one. A box-classifier and a 1-class-SVM are implemented for this second stage.

A comparative assessment of the methods was done using MSTAR data and a fully polarimetric data set provided by QinetiQ. Related ROC curves are presented.

6237-29, Session 5

Dependence of automatic target recognition accuracy on synthetic aperture radar phase distortion

L. J. Montagnino, Raytheon Missile Systems

The performance of automatic target recognition (ATR) systems is a function of both the image quality of the sensed image and the image quality of the signature model used in the ATR training process. This paper reports the performance of an ATR system as a function of synthetic aperture radar (SAR) image quality parameters including total clutter-to-noise ration (TCNR) and phase history error. The image quality perturbations are obtained by introducing controled degredations into the MSTAR public release data. Two classifiers, a statistical model-based classifier of DeVore, et al., and an optimal tradeoff synthetic discriminant function (OTSDF), are used to examine the classification performance of the ATR system as a function of TCNR and phase history error for both the training and test data.

6237-30, Session 5

Generalized bundle adjustment for joint target recognition and image registration

E. M. Lavely, BAE Systems Advanced Information Technologies; E. P. Blasch, Air Force Research Lab.

We consider the joint problem of sensor data registration and automatic target recognition. We pose the joint inverse problem for sensor model and object (target) geometry for optimal model parameter recovery. In this process, sensor-to-target and sensor-to-sensor (for multi-sensor fu-

sion) geometric parameters are simultaneously refined. The approach exploits the coupling between predicted model features and hypothesized target-sensor geometry. The distance metric for feature correspondence may be many-to-one or one-to-one, and multiple feature classes may be used (e.g. point interest operators such as corners, edges, and others). Robustness is achieved through the use of search method combining global and local search methods (to avoid final convergence to local minima) with a robustified least-squares cost function that down-weights outliers in feature correspondences. Various robust kernel functions may be used. Our approach represents a generalized bundle-adjustment method and displays increasing utility as the number of multiple-views (from similar or different sensor modalities) increases. The Jacobian and Hessian structure of the objective function with respect to the free-parameters of the problem reveals the target-sensor geometry coupling, and may be exploited in the bundle adjustment process for efficient optimization. In general, the approach can update internal sensor parameters (such as calibration) as well as external parameters (such as platform geometry). Our approach combines well-developed methods in photogrammetry, computer vision and automatic target recognition to yield a principled, model-based methodology for joint registration and target pose estimation thereby providing a useful methodological advance for automatic target recognition applications. Example applications to SAR and LADAR data are considered.

6237-31, Session 5

Attaining desired ATR performance using non-forced declaration ROC curves

E. P. Blasch, J. D. Leonard, Jr., Air Force Research Lab.

Standard automatic target recognition (ATR) systems generate a receiver operator characteristic (ROC) curve based on a forced choice declaration. Since a ROC plots the hit rate versus the false alarm rate, it is used to determine a hard threshold from which to determine the “best” operating point. ATR systems are not end products, but are integrated with Image Analysts for target assessment. There are ongoing efforts to fuse ROC curves, one form the ATR algorithm and one from the Image Analyst. Fusing ROC curves implies forcing the ATR algorithm to make a declaration which can lead to an incorrect analysis. In this study, we seek to assess a non-declarative ROC curve forming a three dimensional analysis of Hit Rate, False Alarm Rate, and undeclared regions of the PDF. The detections within this region of un-declaration would then be delivered to the IA for assessment and further analysis. In this way, the undeclared probability distribution function (PDF) will become better characterized and with time, the overall performance of the ATR can be improved by utilizing declarations from the IA. This paper highlights (1) the need for non-forced declaration analysis of an ATR algorithm, (2) presentation of a 3D ROC for ATR evaluation, and (3) an example using an ATR algorithm for target recognition.

6237-32, Session 5

Improved ATR value through enhancement accommodations and affordability

T. D. Ross, L. Goodwon, Air Force Research Lab.

Abstract not available

6237-33, Session 6

Detecting moving targets in clutter in airborne SAR

D. M. Zasada, The MITRE Corp.

Abstract not available

6237-34, Session 6

SAR change detection MTI

G. J. Owirka, BAE Systems Advanced Information Technologies

Abstract not available

6237-36, Session 6

An iterative approach for moving target detection and geolocation in SAR

T. L. Lewis, Air Force Research Lab.

Our proposed research is to focus and geolocate moving targets in synthetic aperture radar imagery. The first step is to estimate the target cross-range velocity using sequential sub-apertures; this is done by forming low resolution images and estimating position as a function of sub-aperture, thus yielding an estimate of the cross-range velocity. This cross-range estimate is then used to bound the search range for a bank of focusing filters. Automatically determining the proper velocity that yields the best focused target defines an equation for the target velocity, however both components of the targets velocity can not be determined from a single equation. Therefore, a second image with a slightly different heading is needed to yield a second focusing velocity, and then having a system of two equations and two unknowns a solution can be obtained. Once the target velocity is known the proper position can be determined from the range velocity. Synthetic data will be used with a point source target and both background clutter and noise added.

The results support the development of staring radars with much larger synthetic aperture integration times in comparison to existing radars. The overall flavor of this approach is to trade-off the development of potentially expensive phased-array technology for GMTI and DOA applications with the potential development of advanced processing methods that show potential for processing data over very large aperture integration intervals to obtain similar GMTI geolocation results as with current phased-array technology.

6237-37, Session 6

Tracking analysis of long-dwell SAR-based MTI

M. J. Minardi, Air Force Research Lab.

Abstract not available

Conference 6238: Acquisition, Tracking, and Pointing XX

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6238-01, Session 1

ARMS dual line-of-site acquisition, tracking, and pointing system

A. Daniels, S. A. Baugh, D. R. Eastman, Boeing-SVS, Inc.

The Aerospace Relay Mirror System (ARMS) is a subscale, dual aperture, laser relay testbed that interfaces with a remote laser source to demonstrate the utility of relay technology, and reduce risk for future directed energy systems. The ARMS payload incorporates two independently articulated 75-cm bifocal gimbaled telescopes, optically coupled for relay operation with large angle, rapid retargeting ability, micro-radian pointing stability, internal alignment control, cooperative uplink tracking, and active target tracking. The receiver telescope gimbal is located at the bottom of the payload to maximize uplink flexibility and the transmitter telescope gimbal is located on the top of the payload to maximize weapon effectiveness. In between the two telescope gimbals is the beam control module, a structure that houses the relay optics, receive and transmit aperture sensors and payload electronics. The structure provides the anchor point for suspension cables that interface with the host airborne platform. The system design is modular, distributing the pointing authority, precision and bandwidth amongst multiple sensors and actuators. Command and control functionality support both manual and autonomous operation for diagnostics, laboratory integration and field experiments.

The objective of ARMS is to demonstrate the potential of relay mirror systems technologies to perform a variety of missions such as target designation, precision strike and intelligence against ground and air targets, as well as ballistic and cruise missile defense. The basic optical layout and the autonomous control of ARMS functionality are presented.

6238-02, Session 1

Practical to tactical: an evolution of the dual line-of-sight experiment

C. D. Stargardt, D. J. Riedle, K. J. Warden, A. A. Lazzaro, F. B. Zoltowski, Boeing SVS, Inc.

In early 2001 Boeing-SVS began an Internal Research and Development (IRAD) project, dubbed the Dual Line of Sight (DLOS) experiment, to perform risk-reduction on the development of the control systems and mode logic for a strategic laser relay mirror system. The DLOS experiment uses primarily Commercial Off-the-Shelf (COTS) hardware and real-time system software, plus internally-designed gimbals and flexible mode logic tools to emulate a scalable relay mirror engagement. The high-level, nominal engagement sequence begins with the laser source gimbal establishing a line of sight with the relay receiver gimbal by closing passive acquisition and fine-tracking loops. Simultaneously, the receiver gimbal closes passive acquisition and fine-tracking loops on the laser source, and a low-power 660 nm alignment laser is propagated through the system. Finally, the transmitter gimbal closes passive acquisition and fine-track loops on a target, and the system propagates a simulated high-energy laser on that line of sight onto target models. In total, the DLOS experiment closes 28 control loops. For the strategic scenario, a model rocket target is illuminated with a light-emitting diode, and tracked by the Boeing-SVS Advanced Reconfigurable Trackers, using a centroid algorithm. The strategic scenario also uses a 532 nm laser to close an active track loop using a Linux tracker. To better align with our business capture strategy, the emphasis of the experiment in 2005 has shifted to emulating an urban tactical engagement, and developing weapon system operator consoles.

6238-03, Session 1

Laser system for cooperative pointing and tracking of moving terminals over long distance

D. S. Grinch, J. A. Cunningham, D. S. Fisher, ITT Industries, Inc.

Abstract not available

6238-04, Session 1

Estimation filters for missile tracking with airborne laser

T. M. Clemons III, George Mason Univ. and Dept. of Defense; K. C. Chang, George Mason Univ.

This paper examines the use of various estimation filters on the highly non-linear problem of tracking a ballistic missile during boost phase from a moving airborne platform. The aircraft receives passive bearing data from an IR sensor and range data from a laser rangefinder. The aircraft is assumed to have a laser weapon system that requires highly accurate bearing information in order to keep the laser on target from a distance of 100-200 km. The tracking problem is made more difficult due to the changing acceleration of the missile, especially during stage drop-off and ignition. The Extended Kalman Filter, Unscented Kalman Filter, 'bootstrap' Particle Filter, and the Gaussian Sum Particle Filter are explored using different values for sensor accuracy in bearing and range, and various degrees of uncertainty of the target and platform dynamic. Scenarios were created using Satellite Toolkit(c) for trajectories from a Southeast Asia launch with associated sensor observations. MATLAB(c) code modified from the ReBEL Toolkit(c) was used to run the EKF, UKF, PF, and GSPF sensor track filters. Mean Square Error results are given for tracking during the period when the target is in view of the radar and IR sensors. This paper provides insight into the accuracy requirements of the sensors and the suitability of the given estimators.

6238-05, Session 1

Characterization and removal of quasi-periodic elevation bias in airborne laser swath mapping data

K. C. Slatton, K. Shih, T. Cossio, W. E. Carter, Univ. of Florida

Airborne Laser Swath Mapping (ALSM) has emerged as an important technology for remotely sensing topography. These sensors can map terrain with vertical accuracies of 5 - 10 cm and horizontal accuracies of 15 - 20 cm. Most ALSM systems employ small beam divergence and scanning optics to approximate point-to-point range measurements by illuminating the terrain with discrete pulses of laser light. This acquisition modality results in an irregularly spaced "point cloud", which must then be gridded or interpolated to reconstruct a dense Digital Elevation Model (DEM). Most ALSM systems designed for surface mapping employ laser pulse rates between 10,000 and 100,000 pulses per second. At nominal operating altitudes of 500 - 1000 m, these configurations yield separation distances between laser footprints on the order of a meter.

DEMs generated from ALSM points often exhibit quasi-periodic biases in the elevations of 10 - 20 cm in the direction of the scanning pattern. While generally not visible over high-relief or vegetated terrain, this corduroy artifact presents difficulties when generating DEMs over smooth surfaces, such as beaches and roads. In this work, data are acquired by the University of Florida ALSM system over a non-vegetated and low-relief area in Pahrump Valley, CA to provide a good example of the corduroy artifact. The raw data are processed into a comprehensive format so that inter-

mediate data, such as aircraft position, attitude, and scanner angle are obtained for every laser shot. The corduroy artifact signal is then estimated and removed from the data. This artifact is prevalent in ALSM data collected by many systems, thus this work will help to improve processing of other ALSM data sets.

6238-07, Session 1

Amplitude-phase adaptive correction of optical waves distortions

V. P. Lukin, Institute of Atmospheric Optics (Russia)

Application of the reciprocity principle to shape the laser beam in the atmosphere requires the total reproduction of the amplitude and the phase of the optical wave received from the beacon in adaptive systems. We are developing the modification of the amplitude-phase inversion (conjugation) algorithms (2 models): first is active masking and if the amplitude is below the amplitude threshold we are losing information about amplitude, and second, we used the phase profiles as a const, and if the amplitude is below the amplitude threshold, hence, we are losing information about phase. In several our publications was shown that when use the algorithm of the phase conjugation acing for compensation distorting influences to atmospheric turbulence, is reached correcting the layers, residing near of the aperture of the source. Correction more remote area principal impossible with use of phase only correction. For full compensation portioned distorting lenses necessary controlling not only phase, but also amplitude of the radiation. One of the possibilities - an use the plate with controlled transparency. The turbulence was assigned by one screen, which was disposed in the middle of the path. The intensity of the distortion changed. The phase of the radiation was formed by ideal system, amplitude - with use of transparency. The initial radius of the beam varied at decision of the problem. As a whole the main result conclude that similar amplitude-phase correction is reasonable to use when shaping the beam with given by distribution to intensities, but its using does not provide the efficient issue to energy of the lazer radiation in turbulent atmosphere. One more effective variant of the decision of the problem amplitude-phase correction and use the two-mirror adaptive system.

6238-08, Session 1

Methodology of furnace unit for growing large optic crystals in LWS

A. A. Abgaryan, ARTGO LLC

In general the Crystal Growth Technology does not have the necessary and sufficient conditions to manufacture large size optic crystals, especially in the Sapphire Crystal. We have a theoretical development on the basis of fundamental laws of physical-science and also have partially been validated through experiments proven in order to grow large size optic Crystals. Our large size Sapphire Crystal Lenses have a unique optical characteristic which can be used in the Laser Weapons Systems (LWS); hence solving one of crucial problem of LWS which is the energetic loss of a laser beam through the atmospheres. This sapphire crystal lens captures the Laser beam from the earth surface, cleans the beam in the Satellite and redirects the laser energy to the precise desired target.

Currently, the development and solution for the temperature and heat-elasticity fields in growth systems and into crystal are considered theoretical. We need to assess the effects of large size sapphire crystal lenses on the optical symmetry of the growing crystal. In The crystal growth technology variations of optical symmetry may cause brittleness of the optical crystals. We use super and correct mathematical computing calculations, using basic fundamental laws of nature regarding optical symmetry in the crystal. This methodology is the basis for our exclusive opportunity to create a feedback between the characteristics of crystal and the heating system of the furnace. The results presented reflect the strain, stress, displacement, and temperature fields in three-dimensional curvilinear coordinates in order to solve generalized problems for large optics.

Also, this software product can be helpful in realizing the practice of the radical “new wave method” for crystal growth technology.

6238-10, Session 1

System integration for the coastal area tactical-mapping system (CATS)

W. E. Carter, K. Shrestha, T. Cossio, K. C. Slatton, R. L. Shrestha, Univ. of Florida

Researchers at the University of Florida are developing a short pulse-length photon counting airborne laser swath mapping instrument for the Coastal Area Tactical-mapping System (CATS) project. The CATS system is designed for high resolution topographic mapping of coastal areas, extending offshore to a water depth of a few meters. The unit has a frequency doubled Nd:YAG micro-laser, with nominal operating parameters of 8,000 pps, 450 picosecond pulse length, and 4.5 μJ per pulse at 0.532 μm wavelength. The laser light is up-collimated and passed through a holographic element to produce 100 small beamlets, arranged in a 10 Å~ 10 square array. The beamlets illuminate a “patch” of terrain approximately 2m Å~ 2m, from a flying height of 600m. The reflected photons are detected by a 100 channel (10 Å~ 10 array) photomultiplier tube (PMT), with micro-channel-plate amplification, and time-of-flight is associated with each return by a multi-channel multi-event timer, with a temporal resolution of 500 picoseconds, corresponding to a one way range of 7.5 cm. A highly versatile Risley prism scanner allows the operator to select many different scan patterns, opening the possibility of using the system for both airborne and ground based applications. The major components of the CATS, including the micro-laser, holographic element, and scanner sub-system are being integrated by Sigma Space Inc., while the PMT and multi-channel multi-event timer sub-system are being integrated by Fibertek Inc. The subsystems are currently nearing the end of laboratory testing, and the initial steps of system-level integration have begun. Laboratory testing, followed by ground and airborne testing, is expected to yield the first CATS data sets by early 2006.

6238-06, Session 2

Autonomous target re-acquisition after image disturbance

L. D. Wren, J. R. Thornton, D. White, J. L. Dale, Octec Ltd. (United Kingdom)

Many Command-Line-of-Sight (CLOS) missile systems use ground-based EO sensors to track the target. Both optical and Infra-Red systems can be affected by launch effects, which can include camera shake on launch and target obscuration due to the missile exhaust plume. Further effects can be encountered during flight including aimpoint disturbance, launch debris and countermeasures.

An autonomous video tracking system (AVT) is required to cope with all of these distractions, whilst maintaining track on the primary target. If track is broken during the engagement, the AVT needs to employ a reacquisition strategy that will enable reacquisition of the primary target with the minimum of delay. This task can be significantly complicated in a cluttered scene.

This paper details such a reacquisition algorithm, the primary purpose of which is to correctly identify the primary target whilst reducing the reacquisition timeline. Results are presented against synthetic imagery and actual missile firings.

6238-09, Session 2

Tracking filter algorithm for automatic video tracking

M. A. McEver, J. E. Kimbrell, L-3 Brashear

In addition to servo control and power amplification, motion control systems for optical tracking pedestals feature capabilities such as electro-optical tracking using an integrated Automatic Video Tracker (AVT) card. An electro-optical system tracking loop is comprised of sensors mounted on a pointing pedestal, an AVT that detects a target in the sensor imag-

ery, and a tracking filter algorithm that commands the pedestal to follow the target. The tracking filter algorithm receives the target boresight error from the AVT and calculates motion demands for the pedestal servo controller. This paper presents a tracking algorithm based on target state estimation using a Kalman filter. The servo demands are based on calculating the Kalman filter state estimate from absolute line-of-sight angles to the target. Simulations are used to compare its performance to tracking loops without tracking filters, and to other tracking filter algorithms, such as rate feedback loops closed around boresight error. Issues such as data latency and sensor alignment error are discussed.

6238-11, Session 2

Orbital ephemeris correction based on real-time observations

J. E. Kimbrell, L-3 Brashear; R. S. Hujsak, Analytical Graphics, Inc.

The motion of a satellite in its orbit is defined by its ephemeris, an algorithm that permits prediction of its position as a function of time. The most common implementation of ephemeredes for earth orbiting satellites are Two Line Elements, or TLEs, published by NORAD. These TLEs can be used to cause a telescope or other tracking system to accurately follow the satellite across the sky even when it is shaded by the earth and cannot be seen. This is an important capability for many applications including satellite laser ranging and optical communications.

Due to the extremely large number of objects in low earth orbit, the published TLEs can be several days or even weeks old. As the TLEs age, both initial acquisition and accurate tracking during the pass become more difficult. Even if the initial acquisition error is manually offset, the path of the satellite and the tracking system quickly diverge.

This paper outlines an approach in which initial acquisition data is used to modify the ephemeris and thereby improve the tracking accuracy for the balance of the pass. The implementation is based on an analytical tool developed by AGI called the Orbit Determination Toolkit, modified for integration with a real-time tracking system. Both simulation and test data are presented.

6238-12, Session 3

Spherical alignment of imagers using optical flow fields

B. Lambert, J. F. Ralph, The Univ. of Liverpool (United Kingdom); L. D. Wren, J. L. Dale, Octec Ltd. (United Kingdom)

Optical flow fields can be used to recover some components of the camera ego-motion: such as velocity and angular velocity. In this paper, we discuss the use of optical flow fields to estimate the relative orientation of two imagers with non-overlapping fields of view. The algorithms proposed are based on a spherical alignment technique which is closely related to rapid transfer alignment techniques that are used to align aircraft inertial navigation systems. Of particular importance is the relationship between the accuracy of the optical flow field (which is dependent upon the complexity of the scene and the resolution of the cameras) and the accuracy of the resultant alignment process.

6238-13, Session 3

Electronic image stabilization based on the spatial intensity gradient

D. R. Droege, L-3 Communications Cincinnati Electronics, Inc.

The presence of parasitic jitter in video sequences can degrade imaging system performance. Image stabilization systems correct for this jitter by estimating motion and then compensating for undesirable movements. These systems often require tradeoffs between stabilization performance and factors such as system size and computational complexity. This paper describes the theory and operation of an electronic image stabilization technique that provides sub-pixel accuracy while operating at real-time video frame rates. This technique performs an iterative search on the spatial intensity gradients of video frames to estimate and refine motion parameters. Then an intelligent segmentation approach separates desired motion from undesired motion and applies the appropriate compensation. This computationally efficient approach has been implemented in the existing hardware of compact infrared imagers. It is designed for use as both a standalone stabilization module and as a part of more complex electro-mechanical stabilization systems. For completeness, a detailed comparison of theoretical response characteristics with actual performance is also presented.

6238-14, Session 3

Study of compact stereoscopic system for target distance estimation

D. J. Bankman, Johns Hopkins Univ.

Distance measurement is required in a variety of fields, including targeting, surveillance, reconnaissance, robotics, and cartography. Today, the most commonly used method for distance measurement is laser ranging. However, laser rangers being active systems require more energy and cost more than passive systems, and they can be detected by the adversary. Stereoscopic vision, a passive system, requires minimal power and can remain hidden from the adversary when stealth is necessary. This study considers stereoscopic vision with a compact, portable, system, and investigates its essential parameters that can be optimized for accurate distance measurement. The main parameters addressed in this study are the distance between the two cameras, the distance to the target, and the kernel size used for correlation between the two images. The distance estimation accuracy is determined as a function of these parameters by comparing the stereoscopic distance to actual target distances. To represent a compact, portable system, the study considered parallel camera pairs placed 6 inches or 12 inches apart. Slant range measurement error is less than 3% when the correlation kernel is at 30 pixels wide, with a camera pair distance of 12 inches, and pixel angular span of 0.46 mrad. When target distance decreases and camera distance increases, the stereoscopic disparity will be greater, providing for a decrease in error. Results suggest that better than 97% range accuracy can be achieved in minimal time with kernel width of 30 to 40 pixels, fitting inside or closely around the target image.

6238-16, Session 3

Automated position estimation of target using view extrapolation

H. Noor, S. H. Mirza, NED Univ. of Engineering and Technology (Pakistan)

View Morphing techniques have widely been applied to generate the views present in between two images. In this paper, it has been emphasized that View Morphing is not limited to generation of images lying within the boundaries of existing images. An approach for extending the concepts of view interpolation to synthesize new views that are NOT present between the given views with reference to time and/or position is presented in this paper. The problem is addressed using View Extrapolation. The issues that are usually not considered in image generation through interpolation, but have to be considered for synthesis of extrapolated images are also highlighted.

The results of this research may specially be applied to various defense-related applications, where the future positions of target may be estimated by considering the images already available. A basic assumption has been made that non-stationary objects will continue their development in the current direction and with unvarying speeds. The problem of view synthesis is solved by dividing it into three broad portions: Prewarping, View Extrapolation and Postwarping. Since, the view is to be generated outside the facet of the existing views, hence it becomes necessary to consider the “time factor” i.e. time interval between the gathering of original images and/or time at which the new view is to be generated. This will

help in finding the motion related parameters of the scene, like speed of objects etc. In order for the user to calculate, in advance, that how close the fabricated image will be to the actual one, a new parameter could be introduced, hereby called as the “Accuracy of Prediction” (AoP). AoP will form a relationship among the various factors that affects the image generation e.g. Number of images considered, positioning of cameras, “time factor”, motion-related parameters of objects, amount of occlusion etc. This paper outlines an algorithm and highlights the issues to be considered to generate future images of both stationary and moving objects using the information in existing ones.

6238-17, Session 4

A MUSIC (multiple signal classification) algorithm for specifying azimuth, elevation, and range of multiple sources

R. R. Zito, Raytheon Co.

The MUSIC (Multiple Signal Classification) algorithm uses the phase difference at different antenna elements of a receiving antenna array to determine the azimuth and elevation angles of a source. This algorithm can be extended to determine the range of multiple sources as well as their azimuth and elevation angles. In this report a generalized MUSIC algorithm is presented that accomplishes this task when the receiving antenna consists of a planar, rectangular, array of receiving elements. Greater range accuracies can be achieved by increasing the signal to noise ratio and/or searching for a solution over a range space with a finer mesh. The mesh employed in this study had a range gate size that was 10% of the range space searched. An increase in range accuracy gained by the use of a finer mesh comes at the price of increased processing time.

6238-18, Session 4

Performance analysis of fuzzy logic particle filter compared to fuzzy IMM in tracking high-performance targets

H. Z. Kamel, W. Badawy, Univ. of Calgary (Canada)

A high-performance target may accelerate at non-uniform rates, complete sharp turns within short time periods, thrust, roll, and pitch; which may not follow a linear model. Even though the interacting multiple model (IMM) can be considered as a multi-modal approach, it still requires prior knowledge about the target model. To overcome this weakness, the fuzzy logic particle filter (FLPF) is used. It is comprised of single-input single-output (SISO); which is presented by fuzzy relational equations. A canonical-rule based form is used to express each of these fuzzy relational equations. The dynamics of the high-performance target are modeled by multiple switching (jump Markov) systems. The target may follow one-out of-seven dynamic behavior model at any time in the observation period under assumption of coordinate turn (CT) model. The FLPF has the advantage that it does not require any prior knowledge of statistical models of process as in IMM. Moreover, it does not need any maneuver detector even when tracking a high performance target; which results in less computational complexities. By using an appropriate fuzzy overlap set, only a subset of the total number of models need to be evaluated, and these will be conditioned on acceleration values close to the estimate. This reduces the computational load compared to the fuzzy IMM (FIMM) algorithm. To achieve the whole range of maneuver variables, more models can be added without increasing the computational load as the number of models evaluated is determined only by the overlap. An example is included for visualizing the effectiveness of the proposed algorithm. For comparison purposes, we simulated a FIMM. Simulation results showed that the FLPF has better tracking performance and less computational load compared to the FIMM.

6238-19, Session 4

Simplified generalized asynchronous track to track fusion filter

A. T. Alouani, Tennessee Technological Univ.; J. E. Gray, Naval Surface Warfare Ctr.

Recently the authors derived a very general (radar based) track to track fusion filter which is applicable to an arbitrary number of asynchronous sensors. The algorithm allows one to account for arbitrary length communication delays between local sensor platforms and the data fusion center, as well as being able to handle data that is out of sequence. To simplify the implementation of such filter, assumptions are made about the communication delays and sensors data rate. Such assumptions allow one to develop a simplified asynchronous track-to-track fusion filter algorithm.

The paper is organized as follows into five sections. Section 2 briefly reviews the literature about the known decentralized filtering techniques and discusses the benefits of asynchronous tracking. Section 3 presents an overview of the recently developed generalized asynchronous filter [1]. Section 4 uses realistic assumptions about the nature of the tracks to be fused that permits the development of a simplified asynchronous track fusion filter.

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Conference 6239: Targets and Backgrounds XII: Characterization and Representation

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Part of Proceedings of SPIE Vol. 6239 Targets and Backgrounds XII: Characterization and Representation

6239-01, Session 1

Informational processes in visual and object buffers of scene understanding system for reliable target detection, separation from background, and identification

G. Kuvich, Smart Computer Vision Systems

Modern target recognition systems suffer from the lack of human-like abilities to understand visual scene and detect and unambiguously identify and recognize objects. Target recognition systems are based on the principles of computer vision. But traditional computer vision can only recognize features from visual information, and it plays an auxiliary role, helping to build or choose appropriate 3-dimensional models of objects and visual scene. As result, the target recognition systems become dysfunctional if target doesn't demonstrate remarkably distinctive and contrast features that allows for unambiguous separation from background and identification upon such features. This is somewhat similar to visual systems of primitive animals like frogs that can separate and recognize only moving objects. However, human vision unambiguously separates any object from its background. Human vision combines rough but wide peripheral and narrow but precise foveal systems with visual intelligence that utilizes both scene and object contexts and resolves ambiguity and uncertainty in the visual information. Perceptual grouping is one of the most important processes in human vision, and it binds visual information into meaningful patterns and structures. Unlike the traditional computer vision models, biologically-inspired Network-Symbolic models convert image information into an "understandable" Network-Symbolic format, which is similar to relational knowledge models. The equivalent of interaction between peripheral and foveal systems in the network-symbolic system is achieved via interaction between Visual and Object Buffers and top-level system of Visual Intelligence. This interaction provides recursive rough context identification of regions of interest in the visual scene, and their analysis in the object buffer for precise and unambiguous separation of the object from background/clutter with following recognition of the target.

6239-02, Session 1

Online road appearance learning and road detection using domain knowledge and high-level reasoning

H. Cheng, J. Cook, Sarnoff Corp.

Identifying road networks in UAV imagery is crucial for many applications such as precision target detection, ID and tracking, and autonomous navigation. However, robust and accurate road detection in high resolution and narrow field-of-view UAV video is a challenging task due to large variation of road appearance caused by lighting, shadow and the material of the road. In this paper, we will demonstrate a new approach to road detection that enables online learning of road appearance in order to achieve adaptive, robust and accurate road detection. The online learning is based on domain knowledge and high level reasoning of the relationship among scene objects.

By maintaining a high level description of an aerial sequence, the system is able to identify failure states within the segmenter and to provide additional information to correct the erroneous behaviour. A motion based vehicle tracker is used to obtain location and velocity data that are combined with the segmented output to construct a graph based representation of the scene. By checking a set of constraints based on the interaction of vehicles and roads the system is able to detect failure and to classify the mode into one of three categories; failure of the segmenter, failure of the vehicle tracker, unanticipated behaviour (i.e. vehicle traversing a corn-field).

Thus feedback can be provided to the system at run-time, and intelligent responses to unforeseen problems can be generated based on the failure mode. This paper focuses on using the contextual information gathered from the sequence to develop a road detection algorithm which is robust to changes in environmental conditions and which can provide accurate classification in scenarios which were not envisaged during the training period.

6239-03, Session 1

Maximizing diversity in synthesized hyperspectral images

O. O. Fadiran, P. Molnar, Clark Atlanta Univ.

Maximum diversity in sample data is required to ensure that results are representative of the entire domain.

In cases where the generation of data is computationally expensive, such as image synthesis, the number of samples should be kept to a minimum with higher density in regions of transitions. Our objective is to synthesize a set of hyperspectral infrared images for the performance evaluation of Automatic Target Recognition algorithms (ATR), using the image synthesizing software DIRSIG (Digital Imaging and Remote Sensing Image Generation). The nature of a synthesized image is determined by numerous input parameters to DIRSIG. The set of resulting images has to be diverse with respect to the degree of difficulty for the ATRs under test.

In order to automatically generate the image database, we model each synthesized image as a function of the input parameters given to the DIRSIG software, whereby each parameter contributes to the variation in the image. A statistical measure of difficulty, called the Clutter Complexity Measure (CCM), is then computed for the individual images.

Due to the computational cost of synthesizing an image gradient based sampling schemes are infeasible for determining those regions of transitions. In this paper, we present a sampling algorithm based on active walker models, in which their behavior is solely determined by the distribution of CCMs from the set of already synthesized images. The effectiveness of our proposed method has been tested on a variety of multidimensional functions. In these tests the sample sets obtained from out method showed better reconstruction accuracy than those using even spaced and random sampling. When applied to sampling the CCM multiparameter space, our adaptive sampling algorithm produced a more diverse image set with respect to degree of difficulty than the other sampling schemes.

6239-04, Session 1

Target classification using curvature scale spaces

H. C. Morris, San José State Univ.; M. M. De Pass, Claremont Graduate Univ.

In this paper, we present a study of target recognition based on curvature measures. The goal of this work is to examine identification algorithms based on contour and surface curvature estimations. Costa and R. M. Cesar [1] have developed fractal and curvature analysis methods for the contours in 2D images. In particular, they have introduced the notion of the curvegram of a contour. This provides a visual representation of how

the curvature changes with scale. This idea has been recently developed by Roerdink et. al. [2] into the more general concept of morphological curvature scale spaces. With their extensions come additional shape measures that allow supervised classification in order to compare this unknown object with one from the knowledge database. These methods, and ways in which that might be visualized using shapelet bases [3], will be presented.

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6239-05, Session 1

Attribution of soil information associated with modeling background clutter

G. L. Mason, R. A. Melloh, U.S. Army Engineer Research and Development Ctr.

This paper examines the attribution of Data fields required to generate high resolution soil profiles for support of Computational Test Beds (CTB) used for countermine research. The countermine computational test beds are designed to evaluate sensors used to locate unexploded ordinances. The CTB derives expected moisture, chemical, and heat migration over time which in turn excites the sensor suite. Bulk soil properties have inherent limits with respect to field data collection. Novel techniques are therefore required to collect and populate a high resolution model for prediction of subsurface discrete objects. This paper presents correlation between spatial variability in texture as related to hydraulic permeability and heat transfer properties of the soil. We seek to provide methods to populate a high resolution soils model supporting consideration of the application of various sensors models. The extracted physical properties are used to exercise models providing a signature of subsurface media and supporting the simulation of detection by various sensors of buried and surface ordnance.

6239-06, Session 1

Adaptive AOTF-based spectrometer for real-time environment monitoring

V. I. Pustovoit, V. E. Pozhar, Russian Academy of Sciences (Russia)

AOTF spectrometers are promising spectral instrument for real-time environment monitoring tasks. For such devices possessing random spectral access we previously have stated a problem of finding an optimal algorithm of spectral point addressing during measurement procedure and some approaches have been suggested. It is presented a self-optimizing algorithm of spectral monitoring, which provides permanent variation of parameters of measurement procedure with use of incoming spectral information. The algorithm is realized for differential optical absorption spectroscopy on base of specialized gas-analytic AOTF spectrophotometer.

6239-07, Session 1

Numerical modeling of magnetic moments for UXO applications

V. Sanchez, Y. Li, M. Nabighian, Colorado School of Mines; D. L. Wright, U.S. Geological Survey

UXO discrimination may be improved by using the information from magnetic moments higher than the dipole, since they contain asymmetry information of buried metallic objects. In practice, the noise level of total-field magnetic data could be high enough to overshadow the response from these higher moments such as the quadrupole. However, the improved signal-to-noise ratio in magnetic gradient data may now allow us to utilize these higher moments.

In our paper, we carry out model studies to examine the dipole and quadrupole behavior of different UXO and fragments. We first obtain the magnetization distribution within a metallic object by solving an integral equation describing the magnetization in a highly permeable 3D object. We then compute the dipole and quadrupole moments from the resultant magnetization distribution. This enables us to quantify and catalogue the relative strength of the dipole and quadrupole moments for different classes of metallic objects.

Our results indicate that the quadrupole contribution of an irregularly shaped object can be up to 5 times higher than that for an axi-symmetric object of the same volume. Realistic forward modelling of the magnetic response of a causative body, thus, must include dipole and quadrupole moments and they should be used in discrimination when the data quality warrants. Our analysis of the relative contribution of the quadrupole for these different objects also show that there exists the practical feasibility to improve UXO discrimination using magnetic gradient data by extending the current model to include quadrupole.

6239-08, Session 1

Analysis of Doppler measurements of people

R. J. Tan, Army Research Lab.

Radar has been used to detect and track vehicles for decades we are now working toward tracking people. One application for automated human detection is for security. Fully polarmetric Ka-band radar measurements were made of people walking and running at multiple depression and incidence angles. A 75 MHz band-width step frequency waveform was used. The received Doppler signature reveals the complex motion of the human body. This unique Doppler signature of walking people presents the possibility for discrimination or classification. Data is presented as range-Doppler maps, spectrogram (Doppler versus time plots), and Doppler spectra. Radar cross section (RCS) statistics are also presented in the form of the probability density function (PDF) and cumulative distribution function (PDF). Variations in RCS, is discussed as it relates to depression angle, incidence angle, and polarization.

6239-09, Session 1

Development of a Terahertz short range imaging model

S. G. O'Brien, D. H. Tofsted, Army Research Lab.

A ray trace model was developed to simulate atmospheric effects upon short range imaging of a scene for a narrow frequency band centered at 650 GHz. The frequency chosen is in the vicinity of a terahertz frequency band atmospheric window. We describe the assumptions that went into this model, including the statistics for the density distribution of atmospheric water vapor, which is one of the main molecular absorbers in this spectral region. We also summarize the results of a measurement program in which point sensors (with a 20 Hz sampling rate) measured wind-advected water vapor density. We examine the validity of the atmospheric absorption statistics assumed in our imaging model through a spectral analysis of the temporal series for absorption coefficient derived from the water vapor density data.

6239-10, Session 2

Hyperspectral signature modeling for terrain backgrounds

J. M. Cathcart, A. D. Sheffer, Jr., R. D. Bock, Georgia Institute of Technology

In this paper we present the results of our efforts to develop a digital hyperspectral signature model for terrain features. The infrared signature

model development was conducted in conjunction with a parallel spectral phenomenology research program devoted to understanding and exploiting spectral data for landmine detection. That effort identified a need for a dynamic hyperspectral signature model to support target detection algorithm development. One requirement of that model was the need for a model of spectral infrared signatures of various terrain features (e.g., soils) that accounts for the impact of various dynamical environmental factors and processes. A discussion of the terrain modeling approach, the underlying analytical basis, and results from the model computations will be presented.

This work is supported under a grant from the Army Research Office.

6239-11, Session 2

Military applications of hyperspectral imagery

X. Briottet, Y. Boucher, ONERA (France); A. Dimmeler, FGAN-FOM (Germany); A. Malaplate, ONERA (France); A. Cini, CISAM (Italy); M. Diani, Univ. di Pisa (Italy); H. H. P. T. Bekman, TNO-FEL (Netherlands); P. B. W. Schwering, TNO (Netherlands); T. Skauli, I. Kåsen, Norwegian Defense Research Establishment (Norway); I. G. E. Renhorn, L. M. Klasen, Swedish Defence Research Agency (Sweden); M. A. Gilmore, D. Oxford, Defence Science and Technology Lab. (United Kingdom)

Optical imaging, including infrared imaging, generally has many important applications, both civilian and military. In recent years, technological advances have made multi- and hyperspectral imaging a viable technology in many demanding military application areas. The aim of the CEPA JP 8.10 programme has been to evaluate the potential benefit of spectral imaging techniques in tactical military applications. This unclassified executive summary describes the activities in the programme and outlines some of the results. More specific results are given in classified reports and presentations.

The JP 8.10 programme started in March 2002 and ended in February 2005. The participating nations were France, Germany, Italy, Netherlands, Norway, Sweden and United-Kingdom, each with a contribution of 2 man-years per year. Essential objectives of the programme were to:

- analyse the available spectral information in the optronic landscape from visible to infrared;
- analyse the operational utility of multi- and hyperspectral imaging for detection, recognition and identification of targets, including low-signature targets;
- identify applications where spectral imaging can provide a strong gain in performance;
- propose technical recommendations of future spectral imaging systems and critical components.

Finally, a stated objective of the JP 8.10 programme is to “ensure the proper link with the image processing community”.

The presentation is organised as follows. In a first step, the two trials (Pirrene and Kvarn) are presented including a summary of the acquired optical properties of the different landscape materials and of the spectral images. Then, a phenomenology study is conducted analyzing the spectral behavior of the optical properties, understanding the signal at the sensor and, by processing spectroradiometric measurements evaluating the potential to discriminate spectral signatures.

Cameo-Sim simulation software is presented including first validation results and the generation of spectral synthetic images. Significant results obtained on measured and synthetic images are shown and discussed with reference to two main classes of image processing tasks: anomaly detection and signature based target detection. Furthermore, preliminary works on band selection are also presented which aim to optimize the spectral configuration of an image sensor. Finally, the main conclusions of the WEAG program CEPA JP8.10 are given.

6239-12, Session 2

Irma 5.1 multisensor signature prediction model

J. C. Savage, D. G. Edwards, Air Force Research Lab.; B. Thai, A. Chow, N. Yamaoka, C. Kim, Northrop Grumman Corp.

The Irma synthetic signature prediction code is developed by the Munitions Directorate of the Air Force Research Laboratory to facilitate the research and development of multi-sensor systems. Irma began as a high resolution, physics-based Infrared (IR) target and background signature model for tactical weapon applications. Since then, a number of significant upgrades to Irma were initiated to include a ladar channel, an improved scene generator for correlated frame-to-frame imagery, and a passive IR/millimeter wave (MMW) channel. In 2000, Irma version 5.0 added circular polarization to the passive channel and a doppler capability to the active MMW channel. In 2002, a multibounce technique was added to the Irma passive channel. The Irma user base now includes over 130 agencies within DARPA, NASA, the Departments of Transportation and Defense, academia, and industry. In 2005, Irma version 5.1 adds a new graphical user interface and upgrades the ladar channel to an object oriented language (C++) with improved polarization effects, time jittering, speckle effects, and atmospheric turbulence. This paper will focus on two areas of the Irma 5.1 development effort: report on the analysis results of the validation and verification of the Irma 5.1 ladar channel, and the software development plan and validation efforts of the Irma passive channel.

6239-13, Session 2

Adaptive Gabor filters for infrared target modeling in the modulation domain

J. P. Havlicek, C. Nguyen, M. B. Yeary, Univ. of Oklahoma

For the first time, we compute joint AM-FM models that characterize infrared targets and backgrounds in the modulation domain. We consider spatially localized structures within an IR image as sums of nonstationary, quasi-sinusoidal functions admitting locally narrowband amplitude and frequency modulations. By quantitatively estimating the modulations that dominate the signal spectrum on a spatially local basis, we obtain a new modulation domain feature vector that can augment the more traditional pixel domain, Fourier spectrum, and multispectral color features that have been used in IR target detection and tracking systems for a long time. Our preliminary studies, based primarily on midwave and longwave missile approach sequences, suggest that: 1) IR targets and backgrounds do typically possess sufficient spatially local AC structure (i.e., texture) for modulation domain techniques to be meaningfully applied, and 2) in the modulation domain, targets tend to exhibit a higher degree of local organization or coherency as compared to naturally occurring backgrounds (we have yet to study typical battlefield clutter systematically in this context). After reviewing the fundamentals of AM-FM image modeling, this paper will focus on a detailed discussion of new techniques for extracting high-quality modulation domain target features from IR images. In particular, we will present a new family of adaptive Gabor filters specifically designed for isolating the dominant modulations in spatial target signatures. Although Gabor filters have not been widely used for IR signal processing, their application is both appropriate and effective in this case where optimal joint time-frequency localization is of paramount importance.

6239-14, Session 2

Integrating CameoSim and MuSES to support vehicle-terrain interaction in an IR synthetic scene

A. R. Curran, J. S. Curlee, ThermoAnalytics, Inc.

Modeling infrared (IR) synthetic scenes typically involves a different paradigm than modeling vehicles and other targets. Ground vehicles are modeled using geometric representations that allow the calculation of 3D heat

conduction and radiation exchange between parts of the vehicle as well as impingement of the exhaust plume. For most synthetic scenes it is not practical to create geometric representations of each blade of grass or of every leaf. For this reason, radiation exchange between the vehicle and the terrain or the effects of plume impingement on the terrain are not often modeled within a synthetic scene.

To address this limitation, MuSES (the Multi-Service Electro-optic Signature code), an infrared signature prediction program developed for modeling ground vehicles and other man-made targets, has been integrated into CameoSim, a broadband scene simulation software system that produces high resolution synthetic imagery of natural terrestrial scenes. To achieve the desired level of integration, a geometric description of the terrain surrounding the target is exported from CameoSim into MuSES; MuSES then calculates the temperature of both the target and the supplied terrain. To minimize artifacts between the temperature prediction of the terrain local to and distant from the target, MuSES terrain thermal models can be specified for use in the greater CameoSim scene. The resulting software tool is capable of modeling large scale IR synthetic scenes that include full thermal interaction between the target and the terrain in an area local to the target.

6239-15, Session 2

Real-time simulation tools in the CHORALE workshop

T. Cathala, J. Latger, OKTAL Synthetic Environment (France); A. Y. Le Goff, DGA/DCE/CELAR (France); P. Gozard, DGA/DSP/Tour DGA (France)

CHORALE (simulated Optronic Acoustic Radar battlefield) is used by the French DGA/DET (Directorate for Evaluation of the French Ministry of Defense) to perform multi-sensors simulations. CHORALE enables the user to create virtual and realistic multi spectral 3D scenes, and generate the physical signal received by a sensor, typically an IR sensor. To evaluate their efficiency in visible and infrared wavelength, simulations tools, that give a good representation of physical phenomena, are used. The first part of this article describes the elements used to prepare data (3D database, materials, ...) for the simulation. The second part explains the physical model, called SE-FAST-IR, used in CHORALE for the Real Time simulation. SE-FAST-IR product is a software set allowing the compilation 3D databases in the infrared spectrum. It enables one to visualize complex and large databases for a wide set of real and pseudo-real time applications. SE-FAST-IR is based on the physical model of the Non Real Time tool of CHORALE workshop. It automatically computes radiance textures, Open GL light source and fog-law parameters for predefined thermal and atmospheric conditions, specified by the user. The third part of this article describes the sensor effect module, called SE-FAST-IR-SENSOR. The last part describes the validation process and future evolutions of the real time software.

6239-16, Session 2

Modeling optical turbulence in the atmospheric boundary layer

D. H. Tofsted, S. G. O'Brien, Army Research Lab.

Continued interest in temporal variations of optical turbulence argues for the development of a model to characterize turbulence evolution under varying conditions for ground-to-ground, ground-to-air, and air-to-ground observation/propagation scenarios. Standard vertical profile models of refractive index structure (Cn2) are available in segmented form, but are here analyzed and combined to produce a single mean model of vertical structure that combines surface layer, boundary layer and upper troposphere effects for the daytime atmosphere. This model eliminates the discontinuities and ambiguities present in previous results. The temporal evolution of the vertical profile is modeled through the coupling of the above profiling method to surface effects characterized with a surface energy budget model. Use of this coupled model provides capabilities for simulating turbulence unavailable previously.

6239-17, Session 2

Marine environment background synthesis using MODTRAN 4

V. Ross, AEREX avionique inc. (Canada); D. Dion, Jr., Defense Research Establishment Valcartier Canada (Canada)

To date, physically accurate and reasonably fast background generation in a marine environment has been an elusive objective. The pursuit has been plagued by slow radiative transfer codes and sea BRDF (bidirectional reflectance distribution functions) implementations that traded accuracy for speed. Recently, new developments in both these fields have finally put this goal into our grasp. Here we show that an accurate and fast sea BRDF model can be implemented into modern radiative transfer codes. In this instance, it is integrated in a well trusted and widely used code, MODTRAN 4, to produce marine environment backgrounds with an acceptable computation time and less tradeoff in accuracy.

6239-18, Session 2

MATISSE: version 1.4 and future developments

P. Simoneau, K. Caillault, S. Fauqueux, T. Huet, L. Labarre, C. Malherbe, ONERA (France)

This paper presents the MATISSE-v1.4 code which computes spectral or integrated natural background radiance images. The spectral bandwidth extends from 765 to 3300 cm-1 (3 to 13 μm) with a 5 cm-1 resolution. Natural backgrounds include the atmosphere, low altitude clouds, sea and land. One of the most particular functionality of the code is to take into account atmospheric spatial variability quantities (temperatures, mixing ratio, etc) along each line of sight of the image. In addition to image generation capability, the code computes atmospheric radiance and transmission along a line of sight with the same spectral characteristics as in imaging mode. In this case atmospheric refraction effects and radiation from high or low altitude clouds are taken into account. A high spectral resolution mode is also available to propagate radiation from a high temperature medium in the same atmospheric state as that used for the image generation. Finally, the code is developed with a modular architecture in order to facilitate its use in conjunction with external codes.

This paper describes the range of functionalities of Matisse-v1.4. Computation results and comparisons with results from other codes are presented, along with future developments : Matisse-v2.0 whose main purpose is the modeling of sea radiance images with a 1 meter spatial resolution.

6239-19, Session 3

Sea-surface simulation in the infrared modeling and validation

F. Schwenger, E. Repasi, FGAN-FOM (Germany)

A physics based 3D simulation of sea surfaces is presented. The simulation is suitable for the pre-calculation of detector images for an IR camera. Synthetic views of a maritime scenario are calculated in the MWIR and LWIR spectral band and the images are compared with collected data from a field trial.

In our computer simulation the basic sea surface geometry is modeled by a composition of smooth wind driven gravity waves. Sea surface animation is introduced by time dependent control of the basic statistics. In addition, choppy waves are included into the model to improve the realism of the rough sea. To predict the view of a thermal camera the sea surface radiance must be calculated. This is done with respect to the emitted sea surface radiance and the reflected sky radiance, using either MODTRAN or a semi-empirical model. Slope-shadowing of the sea surface waves is considered, which strongly influences the IR appearance of the sea surface near the horizon. MWIR and LWIR simulations are shown of sun glint as well as of whitecaps which depend upon wind velocity.

For validation purposes appropriate data sets (images and meteorologi-

cal data) were selected from field measurements. A simple maritime scenario including a floating foreground object has been prepared and views of two different thermal imagers, similar to those used in the field trials, have been simulated. The validation is done by visual inspection of measured and simulated images and in addition by numerical comparison based on image statistics. The results of the comparison are presented.

For an accurate reflectance calculation it is necessary to consider the maritime sky. The model is improved by inclusion of a static two-dimensional cloud layer. The cloud distribution is controlled by measured data (power spectral density and temperature distribution).

6239-20, Session 3

Validation of ShipIR (v3.2): methodology and results

D. A. Vaitekunas, W. R. Davis Engineering, Ltd. (Canada)

The naval ship infrared signature model and naval threat countermeasure simulator (ShipIR/NTCS) developed by W.R. Davis Engineering Ltd has undergone extensive validation since its adoption as a NATO-standard, and has been accredited by the US Navy for Live Fire Test and Evaluation of the DDG class warship and Preliminary Design of the DD(X) destroyer. ShipIR is now undergoing accreditation review for use in the Contract Design and Live Fire Test and Evaluation of DD(X). Validation has played a key role in the model development by assessing current accuracy, identifying key areas of improvement, and tracking achievements made by each new release. This paper describes some of the recent improvements in full-ship infrared (IR) signature measurement and model prediction based on the measurements and predictions of an unclassified Canadian research vessel (CFAV Quest). The results show how some of the more recent trial input parameters and model improvements (radiosonde input, ship surface optical properties, atmosphere-scattered solar irradiation, and large-scale Reynolds Number) have had a significant impact on signature prediction accuracy.

6239-21, Session 3

Determination of apparent areas in temperature intervals in registered IR images and thermal simulations

M. Georgson, M. Hörnberg, BAE Systems Hägglund (Sweden)

In the process of controlling and improving the IR signature, thermal simulations and IR registrations are necessary. This allows the major hot spots to be identified and suitable measures can be applied. For closer analysis of the platform temperature, the surface can be divided into temperature segments. By keeping track of the area size of a certain temperature above the ambient air or any other chosen reference, the comparison of the IR signature difference in different designs and the evaluation of countermeasures applied to the platforms are simplified.

For this purpose, software that sorts the apparent areas in a RadTherm IR model and IR registration of a platform in different temperature intervals has been developed. The software offers the possibility to choose any number of temperature intervals as well as the interval sizes. For each temperature interval, statistical parameters such as mean temperature, median temperature, distribution function and standard devia-tion are available.

For an IR registration, the area to be analyzed has to be defined by indicating a closed area. This is done manually by means of a series of polygons and prevents parts of the background to be added to the platform area.

The software is written in Matlab and the format is at the moment limited to RadTherm case files and IR registration in .m format.

6239-22, Session 3

Validation of IR computation codes by confronting their results with measures on a solid aluminum composite propellant rocket motor plume

A. P. Boischot, ONERA (France)

Infrared signatures of missiles plume are usually computed by using a set of flowfield and radiative codes. The flowfield code solves the aerothermochemical equations from the motor's combustion chamber to the exhaust plume, and the radiative code integrates the radiative transfer equation in the plume, using the flowfield results. Two main factors account for the discrepancies observed between the simulation and the experiment: the realism of the physical simulation and the accuracy of the input parameters used by the codes. Despite extensive measurements, there are still a lot of uncertainties about the alumina particles (morphology, chemical composition, optical properties) and these parameters have an important impact on IR radiation. This is why an experiment has been conducted on a small scale composite motor in order to get information about: firstly the thermodynamic conditions and the radiative properties of the plume; and secondly the physical and radiative properties of the particles present in the flowfield.

The experimental setup is composed of the following instruments: a nephelometer which measures the particle size distribution, IR cameras and a spectrophotometer which provide the integrated and spectral radiance of the plume. During the firing, particles are collected in the flowfield for their size and composition to be analyzed. Apart from this experiment the optical properties of alumina are measured in the infrared spectral band at high temperature by means of a levitation setup. The optical indices of the alumina are used both by the inversion process which gives the size distribution and by the radiative computation code. The particles size distribution is an entry data for the Navier Stokes computation code.

The computation of the gas and particles flowfield are compared to the infrared radiance map.

6239-23, Session 3

Validation methodology and robustness study of a infrared radiance contrast prediction model

S. Barbe, ONERA (France)

Infrared synthetic imagery simulators are commonly used for validation of infrared imaging terminal guidance missile performances. A high level of confidence for infrared synthetic imagery simulation is needed. The prediction fiability depends on radiance model quality and input parameters knowledge.

A infrared radiance contrast prediction model was developped at ONERA to study environmental and target/background characteritics effects on contrasts in infrared scene. The aim of this study is to compare the prediction robustness in middlewave and longwave infrared spectral bands (MWIR, LWIR), and to estimate input parameters uncertainties on the prediction quality.

This paper presents the validation methodology and results from the validation study.

A specific validation criteria is used to evaluate the model ability to predict the presence or the lack of contrast between two objects separated by a line (segment). Radiance contrasts simulated are compared to measured contrasts on the PIRRENE test site located 30 km south west of Toulouse, France.

Model validation needs a large number of conditions to surround the application domain.

The specified conditions are: 2 climatologicals conditions (summer, winter), 2 meteorologicals conditions (clear sky, cloudy sky) and 28 segments combining 7 materials and 3 geometries (horizontal/ horizontal, vertical/ horizontal et vertical/vertical). MWIR and LWIR Radiance contrasts are simulated for each condition on complete durnal cycle with 15 minutes

sampling. At the end, simulated model outputs uncertainties (by propagation of input data uncertainties in computational model) and radiometric measurements uncertainties are used to estimate prediction robustness with good level of confidence.

6239-24, Session 3

Smart ammunition behavior in a virtual battlefield

P. Gozard, DGA/DSP/Tour DGA (France); T. Cathala, OKTAL Synthetic Environment (France)

To perform multi-sensors simulations, the French DGA/DET (Directorate for Technical Evaluation of the French Ministry of Defense) uses CHORALE (simulated Optronic Acoustic Radar battlefield). CHORALE enables the user to create virtual and realistic multi spectral 3D scenes, and generate the physical signal received by a sensor, typically an IR sensor. This article presents how the expertise is made to evaluate smart ammunition with laser guidance in a virtual battlefield with the environment CHORALE and the workshop AMOCO. The scene includes background, targets, a laser to designate and ammunition. The laser source is reflected by a target in the battlefield and the laser receiver is linked with ballistics model and guidance model via a simulation framework. Each tools are explained to understand the physics phenomena in the scene to take into account atmospheric transmission, radiative parameters of objects and countermeasure devices. Then numeric models are described as the different ballistics models 3 DOF or 6 DOF, sensor model. The step of ballistics calculation gives the cadence of the global simulation through the simulation framework. The 4 quadrants sensor provides gap between the center of optical way and the barycentre of the spot on the sensitive surface computed by a spot weighted method. These data are provided to the guidance and ballistics model to calculate a new position and a new view of the scene with the designated target in the field view. Finally, this paper explains some results of the evaluation compared with the true behavior after tests on proving ground. Then future evolutions are presented to perform similar evaluation with other intelligent ammunition in a real-time model.

6239-25, Session 3

Comparison of thermal modeling and experimental results of a generic model for ground vehicle

A. B. Lessin, A. Reinov, Y. Bushlin, Institute for Advanced Research and Development (Israel)

Reliable modeling of thermal signature of ground vehicles placed in a background scenario is required for many applications. Such modeling should consider the complex nature of the object geometry and structure, inner heat-sources and operational conditions. There may be also large uncertainty in some of the physical properties of the materials and paints of which the target is constructed. Variations in the air/ground temperatures, wind, solar load and physical processes on the target surface (dust, dew, rain) also contribute to the complexity of the thermal problem and remarkably affect the target and background IR signatures.

To investigate the above mentioned phenomena and for evaluating the ability of code RadTherm to model them properly, a simple benchmark model of a typical ground vehicle - CUBI was developed. CUBI combines both representative features of a generic ground vehicle and geometrical simplicity that enables carefully examination of the numerical simulation results.

The CUBI model is made of mild-carbon steel, 4-mm thick plates with internal thermo-isolation of 10-mm foamed polyurethane. The model was placed in typical desert environment for a long-term observation of its temperature regime (measured by a set of installed thermocouples).

The obtained experimental data were compared to the results of numerical predictions of the code RadTherm. Typical calculations of CUBI were performed with a numerical mesh consisting of 1400 elements and 1402 thermal nodes.

Systematic comparison between experimental data received in natural desert environment and RadTherm prediction for various conditions was performed. The study revealed a problem in the RadTherm prediction. The maximal accuracy of the view-factor calculations achieved in RadTherm is insufficient, especially when thermal isolators are under investigation.

6239-26, Session 3

Mapping energy balance fluxes and root zone soil moisture in the White Volta Basin using optical imagery

J. M. H. Hendrickx, S. Hong, New Mexico Institute of Mining and Technology; H. Compaore, C. Rodgers, P. Vlek, Univ. Bonn (Germany); J. Friesen, N. C. Van der Giesen, Technische Univ. Delft (Netherlands)

Accurate information on the distribution of energy balance fluxes and soil moisture is critical for evaluation of background characteristics worldwide. Since these fluxes and soil moisture are subject to rapid changes in time and space, it is impossible to determine their spatial and temporal distributions over large areas from ground measurements. Therefore, prediction from remote sensing is very attractive as it enables large area coverage and a high repetition rate. In this study, the New Mexico Tech implementation of the Surface Energy Balance Algorithms for Land (SEBAL) is used to estimate net radiation, soil heat flux, sensisble and latent heat fluxes, and root zone soil moisture in the White Volta Basin in West Africa using LandSat TM images (resolution 30 m) and MODIS images (resolution 1000 m).

6239-27, Session 3

Use of a vision model to quantify the significance of factors effecting target conspicuity

M. A. Gilmore, Defence Science and Technology Lab. (United Kingdom)

Abstract not available

6239-28, Session 4

FLUENT-based modeling of rocket exhaust signatures

J. L. Rapanotti, Defence R&D Canada/Valcartier (Canada)

Commercially available fluid-dynamics solvers, such as FLUENT, are being developed to analyze and design missiles of increasing complexity. These robust solvers can be further adapted to predict spectral radiation directly. While retaining the capability to predict signatures from underexpanded axisymmetric rocket exhaust typical of most rockets, this new capability can be extended to include subsonic missiles, such as sea-skimmers, ballistic missiles operating in near-vacuum conditions and side-discharging rockets for manual and semi-automatic command missile guidance. The preliminary results presented in this study suggest that when combined with available atmospheric models, these comprehensive codes can be used to develop improved threat detection and missile guidance optics.

6239-29, Session 4

Acquisition and analysis of a spectral and bidirectional database of urban materials over Toulouse (France)

S. Lachérade, S. Pallotta, C. Miesch, X. Briottet, B. Tanguy, ONERA (France); H. Le Man, IGN (France)

Abstract not available

6239-30, Session 4

Scene generation

V. R. Hahn, Raytheon Missile Systems

Abstract not available

6239-31, Session 4

Automatic 3D virtual scenes modeling for multisensors simulation

T. Cathala, J. Latger, OKTAL Synthetic Environment (France); A. Y. Le Goff, DGA/DCE/CELAR (France); P. Gozard, DGA/DSP/ Tour DGA (France)

SEDRIS that stands for Synthetic Environment Data Representation and Interchange Specification is a DoD/DMSO initiative in order to federate and make interoperable 3D mocks up in the frame of virtual reality and simulation. This paper shows an original application of SEDRIS concept for research physical multi sensors simulation, when SEDRIS is more classically known for training simulation. CHORALE (simulated Optronic Acoustic Radar battlefield) is used by the French DGA/DCE (Directorate for Test and Evaluation of the French Ministry of Defense) to perform multi-sensors simulations. CHORALE enables the user to create virtual and realistic multi spectral 3D scenes, and generate the physical signal received by a sensor, typically an IR sensor. In the scope of this CHORALE workshop, French DGA has decided to introduce a SEDRIS based new 3D terrain modeling tool that enables to create automatically 3D databases, directly usable by the physical sensor simulation CHORALE renderers. This AGETIM tool turns geographical source data (including GIS facilities) into meshed geometry enhanced with the sensor physical extensions, fitted to the ray tracing rendering of CHORALE, both for the infrared, electromagnetic and acoustic spectrum. The basic idea is to enhance directly the 2D source level with the physical data, rather than enhancing the 3D meshed level, which is more efficient (rapid database generation) and more reliable (can be generated many times, changing some parameters only). The paper concludes with the last current evolution of AGETIM in the scope mission rehearsal for urban war using sensors. This evolution includes indoor modeling for automatic generation of inner parts of buildings.

6239-32, Session 4

The Standoff Aerosol Active Signature Testbed (SAAST) at Lincoln Laboratory

J. M. Richardson, J. C. Aldridge, D. C. Harrison, A. G. Hayes, E. L. Hines, L. A. Jiang, K. I. Schultz, MIT Lincoln Lab.

The Standoff Aerosol Active Signature Testbed (SAAST) is the aerosol range within the MIT Lincoln Laboratory's Optical System Test Facility (OSTF). Ladar is an important tool for precise target acquisition, discrimination, and ranging. Missile effluent, particularly that from solid fuel, can mask Ladar signals, reducing system performance. Currently, calculations of scattering from effluent are in disagreement from measurements. This could be due to either uncertainty in effluent density or in scattering cross sections. The SAAST is specifically designed for measuring polarization-sensitive scattering cross sections of laboratory-generated particulate samples at multiple wavelengths and angles. Measurements made at oblique angles are highly sensitive to particle morphology, including complex index of refraction and sample shape distribution. Samples can represent, for example, collected effluent dust. The SAAST has recently undergone a dramatic upgrade, improving sensitivity, flexibility, sample generation, sample verification, and level of automation. Several measurements have been made of terrestrial dust and other samples. We will present the details and capabilities of the SAAST along with the results of recent measurements.

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6240-01, Session 1

Quantifying surface normal estimation

R. B. Reid, Air Force Institute of Technology

An inverse algorithm for surface normal estimation was developed and the impact of a priori information required for surface normal estimations quantified. Building on existing works that calculate the degree of linear polarization (DOLP) and the angle of polarization (AOP) for a given surface normal in a forward model from target to calculation of the DOLP and AOP, this research quantifies the impact of a priori information with the development of an inverse algorithm to estimate surface normals from thermal emissions in long-wave infrared (LWIR). The inverse algorithm begins with simulating a micropolarizer infrared focal plane array capturing LWIR intensity images which are then converted to Stokes vectors. Next, the DOLP and AOP are calculated from the Stokes vectors. Lastly, surface normals are estimated assuming perfect information about the imaged scene. A sensitivity analysis is presented to quantitatively describe the a priori information's impact on the estimation of surface normals. Simulations explored viewing angle (θv), surface roughness (σ), and the target's surface temperature (T) at a given wavelength of observation (λ). Index of refraction (η) and emissivity (ε) were explored indirectly by simulating different target materials. Future laboratory results will be compared to the simulations to confirm the validity of the inverse algorithm for surface normal estimation.

6240-02, Session 1

Characterization and analysis of infrared images

A. J. Raglin, A. Wetmore, D. L. Ligon, Army Research Lab.

With the recent availability of imagery from new modes of sensors we are exploring methods of processing this data. One type of imagery is acquired by measuring the polarization state of each image pixel; information which is sensitive to geometry and material differences that can enhance conventional IR imagery. Images can be enhanced by understanding the polarization of both the emitted and reflected radiation from the objects in the scene. Therefore, it is generally agreed that polarimetric images may be able to reveal information about objects or features within a scene that are not available through other imaging techniques. The additional information can support different approaches to segmentation, detection, and recognition of objects or features in the images. Radar processing serves as an example of using horizontal and vertical polarization component data for use in target detection.

In this work sample images are obtained and information about the values of their Stokes parameters is analyzed. We have explored several standard measures from polarimetry in addition to the raw Stokes parameters and evaluated these parameters across the images for spatial trends of both backgrounds and targets.

6240-03, Session 1

Application of passive imaging polarimetry in the discrimination and detection of different color targets of identical shapes using color-blind imaging sensor

A. M. El-Saba, M. S. Alam, A. Surapaneni, Univ. of South Alabama

We extend the application of passive imaging polarimetry to effectively discriminate and detect different color targets of identical shapes using color-blind imaging sensor. For this case of study we show that traditional color-blind polarization-insensitive imaging sensors that rely only on the spatial distribution of a target suffer from high false detection rates. We show that a polarization-sensitive imaging sensor can successfully discriminate and detect the true target based on its color, in the presence of multiple identical shape targets. We highlight the main advantages of using our proposed polarization-based imaging sensor.

6240-04, Session 1

Shape extraction from passive polarimetric images

V. Thilak, D. G. Voelz, S. Damarla, C. D. Creusere, New Mexico State Univ.

Passive polarization based imaging has attracted attention from the optics and signal processing community due to its utility in pattern recognition and computer vision. Passive polarimetric images contain information about a scene that complements information in the intensity images. This information has been exploited for improving pattern recognition tasks including target detection and recognition, material classification and automatic shape detection (extraction). Goudail et al proposed a target segmentation algorithm based on polygonal active contours and the minimum description length principle. The targets were constructed from transparent cellophane tape on a cardboard background in the above study. In this paper, we extend the above work by considering more complex shapes including three-dimensional objects such as cylinders. We consider simple edge detection strategies such as the Sobel operator as well as other advanced segmentation methods shape extraction. These methods are applied to polarimetric image data gathered in the laboratory with a linear polarizer. The experimental results validate the utility of passive polarimetric data in shape detection and extraction.

6240-05, Session 2

Real-time extraction of polarimetric information at the focal plane

V. Gruev, J. Van der Spiegel, K. Wu, N. Engheta, Univ. of Pennsylvania

Traditional imaging systems focus on converting light's intensity and color property into suitable electronic signals. An important property of light, polarization is ignored with these traditional imaging systems. Polarization vision contains information about the imaged environment, such as surface shapes, curvature and material properties. Real time extraction of polarization properties would further allow synergy with traditional adaptive spatiotemporal image processing techniques for synthetic imaging. Therefore, we have developed an image sensor with real-time polarimetric extraction capability at the focal plane. This novel imaging system is the first of its kind to compute Stockes parameters at the focal plane in real-time. In order to fully describe the polarization state of light in nature, three linear polarized projections or two linear polarized projections in combination with the total intensity are needed. The latter method is preferred for focal plane implementation since it only requires two thin film polarizers offset by 45 degrees, patterned and placed on top of each other. Hence, we have adapted the later approach in order to fabricate a two layer micro polarizer array with total thickness of around 20 * m. The micro polarizer array is mounted on top of the imaging sensor. The image sensor is composed of a 256 by 256 photo pixel array, noise suppression circuitry and analog processing circuitry for polarimetric computation. The image sensor was fabricated in 0.18 * process with 10 * m pixel pitch and

75% fill factor. Block-parallel pixel read out is employed in order to compute Stockes parameters on a neighborhood of 2 by 2 pixels. The Stockes parameters are presented together with the noise suppressed intensity image. Experimental data from the polarimetric imaging system is also presented.

6240-06, Session 2

Imaging spectropolarimetry of cloudy skies

N. J. Pust, J. A. Shaw, Montana State Univ.-Bozeman

The polarization state of atmospheric radiance varies with cloudiness and cloud type. We have developed a dual-field-of-view imaging spectropolarimeter for measuring atmospheric polarization in five spectral bands from 450 to 700 nm. This system can be used to measure polarizatin with either a fisheye or telephoto optical front end, allowing studies of all-sky and target polarization. We present and describe measurements of sky polarization with clear-sky and variably cloudy sky conditions. In clear skies, we observe a slight upward trend of the degree of polarization with wavelength, in agreement with previous observations. Clouds generally reduce the degree of polarization, and we are studying the variation with cloud type and cloud distribution.

6240-07, Session 2

Material classification based on multiband polarimetric images fusion

Y. Zhao, Q. Pan, Northwestern Polytechnical Univ. (China)

Polarization adds another dimension to the spatial intensity and spectral information typically acquired in remote sensing. Polarization imparted by surface reflections contains unique and discriminatory signatures which may augment spectral target-detection techniques. With the development of multi-band polarization imaging technology, it is becoming more and more important on how to integrate polarimetric, spatial and spectral information to improve target feature detection and discrimination. In this study, investigations were performed on combining multi-band polarimetric images through false color mapping and wavelet integrated image fusion method. The objective of this effort was to extend the investigation of the use of polarized light to target detection and material classification. As there is great variation in polarization in and between each of the bandpasses, and this variation is comparable to the magnitude of the variation intensity. At the same time, the contrast in polarization is greater than for intensity, and that polarization contrast increases as intensity contrast decreases. It is also pointed out that chromaticity can be used to make targets stand out more clearly against background, and material can be divided into conductor and nonconductor through polarization information. So, through false color mapping, the difference part of polarimetric information between each of the bandpasses and common part of polarimetric information in each of the bandpasses are combined, in the resulting image the conductor and nonconductor are assigned different color. Then panchromatic polarimetric images are fused with resulting image through wavelet decomposition, the final fused image have more detail information and more easy identification. This study demonstrated, using digital image data collected by imaging spectropolarimeter, Multiband imaging polarimetry is likely to provide an advantage in target detection and material classification.

6240-08, Session 2

Fuse spectropolarimetric imagery by D-S reasoning

Y. Zhao, Northwestern Polytechnical Univ. (China)

The detection of low signature objects in cluttered backgrounds is a crucial problem in remote sensing. In the past few years, imaging spectral and polarimetric sensors have been evaluated for this application. As the reflection or emission spectral signatures depend on the elemental composition of objects residing within the scene. The polarization state of radiation is sensitive to surface features such as relative smoothness or roughness. But each character (spectral, polarimetric or spatial character) giving an incomplete representation of an object of interest, it expected that the combination of complementary and redundant characters would be contributed to reduce the false alarm rate, improve the confidence in the target identification and the quality of the scene description as a whole. Imaging spectropolarimetry provides effective mean to acquire spatial, spectral and polarimetric information of scene. This paper presents a study of spectropolarimetric image data set recorded from imaging spectropolarimeter located on top of building. The sensors operated in the visible band and near infrared band. The LPD anomaly detection algorithm was separately applied to polarimetric data sets of each band (Stokes images, degree of polarization image and angle of polarization image) to obtain a series of two dimensional map of objects and false detection. As there are some conflictions among these maps, D-S reasoning is used to combine these maps to improve the detection rate and low false rate. Through experiment and simulation, we conclude that this fusion algorithm can be well applied to enhance the detection performance.

6240-09, Session 3

Polarization patterns and symmetries as a manifestation of helicity preserving characteristics of scattering media

C. Schwartz, M. A. Vonniederhausern, A. Dogariu, Univ. of Central Florida

Polarization patterns in backscattering from random media were observed over the years in many experiments and obtained in Monte-Carlo simulations. The spatially resolved polarization measurements are used to derive polarization resolved Muller matrices which can be used to gain information about the scattering media. The polarization patterns and the subsequent symmetries of the spatially resolved Muller matrix of scattering media can be explained in terms of relative contributions of helicity preserving (i.e. maintaining the state of circular polarization of an incident field) scattering paths and helicity mixing paths. Helicity preserving paths are a characteristic of a medium of large scattering particles with a pronounced forward scattering. Helicity mixing paths are a characteristic of smaller particles with a more isotropic scattering phase function. Accounting for the geometrical phase (or the so called Berry phase) acquired for each type of path leads to an explanation of the symmetry properties between the Muller matrix elements and within the spatially resolved elements. An interesting aspect of the polarization patterns which involves the basic physical principal of conservation of the total angular momentum of light will be discussed.

6240-10, Session 3

Reflective and polarimetric characteristics of urban materials

D. G. Jones, D. H. Goldstein, J. C. Spaulding, Air Force Research Lab.

Object detection and recognition has broad commercial and military applicability. Successful discrimination of targets/objects is a function of many operational conditions such as sensing modality, material properties, and environmental context (e.g., urban, agricultural, forest, desert). This paper describes a methodology to measure and analyze reflective and polarimetric features of man-made materials that are prevalent in urban environments. The measurement instrument is a spectropolarimetric reflectometer operating in the near and short-wave IR spectral regions. Resulting measurements are the bi-static reflectance distribution function (BRDF) and full Mueller matrix for each material investigated. Finally, a separability analysis of derived features is also provided.

6240-11, Session 3

Modeling polarization effects in aiding detection of submerged objects

M. A. VonNiederhausern, C. Schwartz, A. Dogariu, Univ. of Central Florida; J. W. Grantham, Northrop Grumman Corp.

Radiative transfer theory of polarized light is applied in a model which is used to perform a trade-off analysis of an airborne laser system for detection of submerged objects. Various aspects of the problem are treated such as the effects of air-water interface, scattering from suspended particulates, reflection from the target and benthic surfaces, as well as illumination and receiver characteristics. Scattering and reflection properties are modeled as Muller matrices for the respective situations - transmission, backscattering and reflection from the various surfaces. The system model takes into account the characteristics of the illumination beam and receiving system, including a full polarization treatment of the illumination. Analysis of the response to both steady state and pulsed illumination is facilitated by taking into account transient polarization effects. An overview of the model will be presented along with data derived both from laboratory measurements and Monte Carlo simulations, both of which are used as input to the model. The model predictions will be eventually tested during field tests.

6240-12, Session 3

Measurement and theory for monostatic Mueller matrix

C. An, Photon Research Associates, Inc.; D. H. Goldstein, J. C. Spaulding, Air Force Research Lab.; K. J. Zeringue, Photon Research Associates, Inc.

Monostatic Mueller matrix measurements of aluminum plates of various roughnesses are presented using a Mueller matrix polarimeter with a dual rotating retarder. The measurements are compared with a theoretical Mueller matrix model derived from the vector Kirchhof diffraction equation. The wavelength of the laser is 1.55 μm. The rms roughness is provided by surface profilometer measurements and the roughness correlation length is estimated by finding the best match between the measured and the model reflectance for varying roughness correlation length. Except one smooth surface, all other aluminum samples studied have roughness ratio (= roughness correlation length/rms roughness) less than 5.

We compare the Mueller matrices between the lab measurement and the theoretical model. The model results show that the off-diagonal elements of the matrix have a symmetry relation and the diagonal elements have nearly the same magnitude implying negligible depolarization for angles less than 30 degree. The lab measurements show that the off-diagonal elements have a symmetry relation for a smooth sample but the symmetry relation is weaker for rougher samples (lower roughness ratios). The lab data also show that depolarization is about 2% for the smooth sample but larger than 25% for the other rough samples for angles less than 30 degree. The smooth surface shows reasonable agreement between the lab data and the model result but the rough samples do not show similar agreement. Possible causes of discrepancy are discussed and improvements for the lab measurement and model are suggested.

6240-13, Session 4

Division-of-amplitude imaging polarimeter for the fast measurement of Stokes vector

A. M. El-Saba, M. S. Alam, Univ. of South Alabama

We present a novel arrangement of fast (milliseconds) measurement of Stokes vector imagery using the concept of division-of-amplitude polarimeter. This polarimeter uses two orthogonal rugged arms separated by a broadband beam splitter. Each arm contains an arrangement of a polarizer and a liquid crystal variable retarder that is tunable in the range of 5-20 milliseconds. The polarizer/retarder arrangement is suitably oriented in each arm to provide the first three Stokes parameters, without any movable parts; thus the Stokes imaging parameters are determined with minimal errors and with simple calibration requirements. Experimental results will be shown.

6240-14, Session 4

Image processing methods to compensate for IFOV errors in microgrid imaging polarimeters

B. M. Ratliff, J. K. Boger, Applied Technology Associates; M. P. Fetrow, Air Force Research Lab.; J. S. Tyo, The Univ. of New Mexico; W. T. Black, Applied Technology Associates

Imaging Stokes vector polarimeters are used in many remote sensing applications. Polarimeters require that several measurements be made under optically different conditions in order to estimate the polarization signature at a given scene point. This multiple-measurement requirement introduces error in the signature estimates and the errors differ depending upon the type of measurement scheme used. Here, we investigate linear three-channel microgrid polarimeters. This type of instrument consists of a mosaic of micro-polarizers at different orientations that are masked directly onto a focal plane array sensor. In this scheme, each polarization measurement is acquired spatially and hence each is made at a different point in the scene. This is a significant source of error, as it violates the requirement that each polarizer measurement have the same instantaneous field-of-view (IFOV). In this paper, we first study the amount of error introduced by the IFOV handicap in microgrid instruments. We then proceed to investigate means for mitigating the effects of these errors to improve the quality of polarimetric imagery. In particular, we examine different interpolation and dead pixel replacement schemes and gauge their performance according to a set of adopted polarization metrics. These studies are completed through the use of both real instrument and modeled data.

6240-15, Session 4

Quantifying DoLP sensitivities in a LWIR microgrid imaging polarimeter

D. L. Bowers, B. M. Ratliff, J. K. Boger, Applied Technology Associates; M. P. Fetrow, Air Force Research Lab.; S. Ortega, D. Wellems, W. T. Black, Applied Technology Associates; J. S. Tyo, The Univ. of New Mexico

Long-wave infrared microgrid imaging polarimeters have been successfully manufactured and employed. Such polarimeters consist of a mosaic of micro-polarizers at different orientations that are super-imposed directly onto a focal plane array (FPA) sensor. Such a measurement scheme allows for video-rate acquisition of polarimetric imagery. As with all IR imagers, FPA fixed pattern noise (FPN) is a serious issue that must be periodically compensated for through nonuniformity correction (NUC) techniques. This is particularly problematic for microgrid imagers due to the spatial differencing nature of polarimetric processing. Depending on the NUC used varying amounts of residual nonuniformity remain in the corrected images. To understand how this manifests as polarization error, we employ several different NUC techniques, i.e., one-point, two-point, multi-point and scene-based, and evaluate the resulting polarimetric imagery. The quality of the polarization imagery is judged according to a suite of standard metrics as well as ones that we have devised. The above studies are completed using data obtained from both a real LWIR microgrid polarimeter and a mathematical model of the instrument.

6240-16, Session 4

Scanning linear polarimeter for aerosol sensing

D. S. Sabatke, S. B. Petroy, T. Lin, M. A. Kuester, Ball Aerospace & Technologies Corp.; B. Karpowicz, Georgia Institute of Technology; P. Kaptchen, E. Coppock, Ball Aerospace & Technologies Corp.

An imaging polarimeter for sensing of aerosol scattering and other atmospheric phenomena has been constructed and tested. The instrument is a testbed for a multispectral system architecture, in which spectral channels are added in a modular fashion using dichroic beamsplitters and dedicated detectors. The testbed operates in a pushbroom scanning mode, with two co-boresighted optical trains. Each optical train features a narrow-band filter, an intermediate image at a slit, collimating optics, an appropriately-oriented Wollaston prism, and two linear detector arrays. Consequently the testbed is capable of determining the first three Stoke components (linear polarization) at a single wavelength. We describe calibration and field testing, and present preliminary data analysis results.

6240-17, Session 4

Imaging polarimeter with enhanced detection range

J. B. Woodruff, A. Lompado, Polaris Sensor Technologies, Inc.

Imaging polarimetry is well known to afford more information than traditional radiometric imagery due to the resolution of the collected light field into its component polarization states. In particular, objects represented in a Degree of Linear Polarization image can display higher contrast over a traditional intensity image and have sparked several investigations into methodologies for designing accurate polarimeters. A key component of this design process is determination of a way to extract the polarization properties of the incident beam without introducing systematic errors such as image motion. Popular designs include those based on Brewster angle incidence, cascaded liquid crystal variable retarders, birefringent wedges, rotating retarders, and the division of aperture. Each method has both merits and drawbacks. For example, the division of aperture sacrifices spatial resolution in exchange for improved temporal resolution. Similarly, errors can be introduced from misalignments of optical train with respect to the multiple detectors required by such a system. Analysis of field and laboratory data, coupled with consideration of the required Stokes and Mueller algebra, and consideration of the particular requirements of a battlefield type mission resulted in an innovative design that maintains the advantages of a polarimetric sensor while not subject to the problems inherent in a polarimeter that researchers have long tried to overcome. Specifically the new polarimeter is inexpensive, robust with no moving parts, effective to the extent that the additional information from a complex device is negligible, and perhaps most significant is the fact that traditional polarimeters at most collect half the incident power in any channel, while this design allows the entire solid angle incident at the entrance pupil to propagate to the detector unscathed.

6240-18, Session 5

Visible Stokes imaging using programmable waveplate based on PLZT ceramic

S. Breugnot, B. F. Pouet, P. Clemenceau, M. De Geuser, Bossa Nova Technologies

We present the theoretical and experimental results of a new polarization component - a programmable waveplate - for polarization imaging in the visible and NIR spectral band. The programmable waveplate is based on PLZT ceramic. PLZT ceramic is a promising component for polarization imaging that exhibits a strong Kerr effect and a fast response time. The advantages of the PLZT ceramic compared to other technical solution are the following: Generation of variable and rotatable programmable waveplate leading to linear and elliptic polarization measurement, fast (Response time ~ few microseconds), low interaction length (0.5 mm) and low cost. The axis and the birefringence of the component are electrically driven and therefore no mechanical rotation is needed. The design, fabrication and test of different components are detailed. The electro-optic behavior of the PLZT ceramic varies with its composition and can be optimized. Measurement of the optical (spectral band, refractive index) and polarization properties, coupled to the measurement of the response time demonstrates the potential of the component. We propose different architecture to integrate it into a polarization imaging system. We demonstrate the use of the component for Stokes polarization imaging in the visible. Images of transmission of polarization components (linear and circular polarizer) and reflection on different materials are presented.

6240-19, Session 5

Characterization of commercial sheet polarizer material

D. H. Goldstein, Air Force Research Lab.

Sheet polarizers were invented by Land in the 1920s. The fabrication of the type of sheet polarizers we use today, i.e. H-sheet polarizers, was described in the basic H-sheet patent issued in 1948. Single polarizer transmittance, and parallel pair and crossed pair transmittance are typically quoted for these polarizers. In this paper we describe spectropolarimetric measurement results for currently available commercial sheet polarizer and sheet retarder material. The measurements cover the nominal spectral region for the polarization elements but also describe performance well beyond the advertised range. Mueller matrices for the elements were measured, and diattenuation and retardance for both polarizers and retarders are presented.

6240-20, Session 5

All-glass broadband VIS-NIR linear polarizer for specialized applications

R. Gafsi, K. R. Rossington, P. A. Schrauth, Corning Inc.

In this paper, the processes and results will be presented for a polarizer covering the wavelength range of visible (VIS) to the near Infra - Red (IR) band. Currently, Corning Incorporated manufactures and commercializes several polarizers for nominal wavelengths ranging from 633 nm to 2100 nm. For each of these polarizers, the polarization bandwidth is about 80 nm, except for Polarcor(tm) WIDE Band product, which has a polarization bandwidth of 370 nm. The all-glass absorptive polarizer discussed in this paper has a polarization bandwidth of at least 400 nm and high Polarization Extinction Ratio (PER) over the bandwidth 600 nm to 1100 nm. The polarizer is monolithic, hence free of epoxy or optical cement. The polarizer spectrum of PER and % transmission without anti - reflection coating will be presented and discussed.

This new polarizer offers excellent optical properties, as well as high durability and consistency, which will offer several advantages and benefits when it is deployed in optical components, devices and systems. The applications for this polarizer may include: polarization dependent optical isolators, polarimetry systems, ellipsometers, electro-optics and liquid crystal modulators, and many other polarization based devices. The new polarizer can be used in specialized governmental applications where Polarcor(tm) glass polarizers are presently used.

6240-21, Session 5

Air-grid polarization splitter for infrared imaging systems

T. Nakano, Y. Tamagawa, Mitsubishi Electric Corp. (Japan)

Brewster Angle Polarization Splitter (BAPS) uses the strong polarization effect caused by Fresnel reflection at Brewster angle. Since transmitted light through a single boundary is only partially polarized, BAPS is generally composed of pile-of-plates. However, this structure restricts the incident light angle because the reflected light becomes rapidly unpolarized as the incident angle changed from the Brewster angle and is unsuited to imaging systems.

In this paper, we propose ‘air-grid’ structure which achieves separation of polarization component of incident light by only a single layer. The air-grid structure is composed of thin and long cavities laid parallel with each others, resembling the wire-grid structure with substitution of air cavities for metal lines, and shows structural birefringence. The refractive indices

of the air-grid structure can satisfy the Brewster angle for the p-component of incident light and the perfect reflection for the s-component at the same incident angle. It is found out that the material of the splitter requires the refractive index of larger than 2.0, so that this structure is adequate for infrared optical materials.

6240-22, Session 6

Transmission ellipsometry of transparent-film transparent-substrate systems: closed-form inversion for the film optical constant

A. R. M. Zaghloul, Georgia Institute of Technology and ITR Technologies Inc; M. Elshazly-Zaghloul, Y. A. Zaghloul, ITR Technologies Inc. and Georgia Institute of Technology

A closed-form formula for the film optical constant is presented. The derivation of the formula itself is not presented to save the reader lots of involved transformations and algebra. The formula in itself is algebraically accurate and does not introduce errors. The effects of experimental errors, random and systematic, are presented. The results are very accurate. The inversion process is very fast, stable, resilient, does not need a guessed close-to-solution or any starting value, always provides the correct answer with no divergence in any case, and is not iterative in nature. Clearly, those are important advantages over the widely used, manufacturer supplied, fitting routines. It provides for real-time applications in research and industry.

6240-23, Session 6

Polarization effects in fiber aboard the Space Interferometry Mission

J. M. Levin, M. G. Young, S. Dubovitsky, L. I. Dorsky, Jet Propulsion Lab.

For precision displacement measurements, laser metrology is currently one of the most accurate measurements. Often, the measurement is located some distance away from the laser source, and as a result, stringent requirements are placed on the laser delivery system with respect to the state of polarization. Such is the case with the fiber distribution assembly (FDA) that is slated to fly aboard the Space Interferometry Mission (SIM) next decade. This system utilizes a concatenated array of couplers, polarizers and lengthy runs of polarization-maintaining (PM) fiber to distribute linearly-polarized light from a single laser to fourteen different optical metrology measurement points throughout the spacecraft. Optical power fluctuations at the point of measurement can be traced back to the polarization extinction ratio (PER) of the concatenated components, in conjunction with the rate of change in phase difference of the light along the slow and fast axes of the PM fiber. Thermal variations are one of the major contributors to this change and can lead to tight spacecraft design requirements. In this presentation, we will discuss our experimentally-validated model which predicts the polarization behavior for various distribution designs, as well as present the thermal performance of various PM components and how this levies thermal control requirements on the spacecraft.

6240-24, Session 6

Transmission polarization-devices using an unsupported film/pellicle: closed-form design formula

A. R. M. Zaghloul, Georgia Institute of Technology and ITR Technologies Inc; M. Elshazly-Zaghloul, ITR Technologies Inc. and Georgia Institute of Technology

We present a comprehensive study of the polarization characteristics of an unsupported film/pellicle in the transmission mode through the use of the transmission ellipsometric function . We determine the behavior of the unsupported film. In addition we identify all possible transmission polarization-devices using the pellicle. We present closed-form design formulae for each and every device, in addition to a unified closed-form design-formula that works for the design of any and all possible devices. It also works for any general transmission polarization-device. Due to the limited size of the paper, we only present a limited number of device characteristics and performance.

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6241-01, Session 1

An algorithmic approach to mining unknown clusters in training data

R. S. Lynch, Jr., Naval Undersea Warfare Ctr.; P. K. Willett, Univ. of Connecticut

In this paper, unsupervised learning is utilized to develop a method for mining unknown clusters in training data [1,2]. The approach utilized is based on the Bayesian Data Reduction Algorithm (BDRA), which has recently been developed into a patented system called the Data Extraction and Mining Software Tool (DEMIST). In the BDRA, the modeling assumption is that the discrete symbol probabilities of each class are a priori uniformly Dirichlet distributed, and it employs a "greedy" approach to selecting and discretizing the relevant features of each class for best performance. The primary metric for selecting and discretizing all relevant features contained in each class is an analytic formula for the probability of error conditioned on the training data. Thus, the primary contribution of this work is to demonstrate an algorithmic approach to finding multiple unknown clusters in training data, which represents an extension to the original data clustering algorithm. To illustrate performance, results are demonstrated using simulated data that contains multiple classes and clusters. In general, the results of this work will demonstrate an effective method for finding multiple clusters/classes in data mining applications. Further, the potential of the methods developed here to reduce the false-alarm rate in real world classifier applications is also discussed.

6241-02, Session 1

Efficient mining of strongly correlated item pairs

S. Li, R. Lee, S. Lang, Univ. of Central Florida

Past attempts to mine transactional databases for strongly correlated item pairs have been beset by difficulties. In an attempt to be efficient, some algorithms produce false positive and false negative results. In an attempt to be accurate and comprehensive, other algorithms sacrifice efficiency. We propose an efficient new algorithm that uses Jaccard's correlation coefficient, which is simply the ratio between the sizes of the intersection and the union of two sets, to generate a set of strongly correlated item pairs that is both accurate and comprehensive. The pruning of candidate item pairs based on an upper bound facilitates efficiency. Furthermore, there is no possibility of false positives or false negatives. Testing of our algorithm on datasets of various sizes shows its effectiveness in real-world application.

6241-03, Session 1

Genetic program-based data mining to reverse engineer digital logic

J. F. Smith III, Naval Research Lab.

A data mining based procedure for automated reverse engineering and defect discovery has been developed. The data mining algorithm for reverse engineering uses a genetic program (GP) as a data mining function. A genetic program is an algorithm based on the theory of evolution that automatically evolves populations of computer programs or mathematical expressions, eventually selecting one that is optimal in the sense it maximizes a measure of effectiveness, referred to as a fitness function. The system to be reverse engineered is typically a sensor, e.g., a radar. Design documents for the sensor are not available and conditions prevent the sensor from being taken apart. The sensor is used to create a database of input signals and output measurements. Rules about the likely design properties of the sensor are collected from experts. The rules are used to create a fitness function for the genetic program. Genetic program based data mining is then conducted. This procedure incorporates not only the experts' rules into the fitness function, but also the information in the database. The information extracted through this process is the internal design specifications of the sensor. Uncertainty related to the input-output database and the expert based rule set can significantly alter the reverse engineering results. Significant experimental and theoretical results related to GP based data mining for reverse engineering will be provided. Methods of quantifying uncertainty and its effects will be presented. Finally methods for reducing the uncertainty will be examined.

6241-04, Session 1

Database architecture for data mining to aid real-time range safety decision in a test range

A. K. Checker, A. R. Raj, Government of India (India)

Flight vehicles carrying sensitive payloads and large amount of propellants pose danger to life and property around launch pad area. There are inherent limitations in existing decision support system and at times the man in the loop is under severe strain while analyzing the real time data of flight vehicle for range safety decision support system. it is essential to use newer technological input for designing flight termination system for handling high speed, high maneuvering and multi -platform based flight vehicles. This calls for extensive trajectory simulation under various flight conditions and failure modes, collection of actual test data of sub systems and past flight data along with geographical , metrological and tracking instrument data to be collected and organized in a data warehouse for data mining. The knowledge discovered in real time using large data base will aid range safety decision making in a complex scenario of flight testing in a test range.

This paper highlights briefly the existing system and its constraints and attempt to evolve an innovative system combining knowledge base and real time data from multiple sensors and fusing the data from similar and dissimilar sensors using stat -vector fusion technique for more reliable and quick range safety decision making.

6241-05, Session 1

Granular computing for data mining

Y. Yao, Univ. of Regina (Canada)

Granular computing, as an emerging research fields, provides a conceptual framework for studying many issues in data mining. This paper examines some of those issues, including data and knowledge representation and processing. It is demonstrated that one of the fundamental tasks of data mining is searching for the right level of granularity in data and knowledge representation.

6241-06, Session 2

Enhanced data mining information assurance by using ISO 17799

W. G. Perry, Western Carolina Univ.

The goal of database mining is to draw unique and valid perspectives from diverse data sets. Insights that are fashioned from closely-held data stores are likely to possess a high degree of information assurance.

The degree of information assurance, however, is in question when external data bases are accessed, combined and analyzed to form new perspectives. ISO/IEC 17799, Information technology-Security techniques-Code of practice for information security management, can be used to establish a high level of information assurance among entities using data mining in the defense, homeland security, commercial and other civilian/commercial domains.

Organizations, meeting ISO/IEC information security standards, have identified and assessed risks and vulnerabilities and have taken significant proactive steps to meet their unique security requirements.

The ISO/IEC standards address twelve domains: risk assessment and treatment, security policy, organization of information security, asset management, human resources security, physical and environmental security, communications and operationsn management, access control, information systems acquisition, development and maintenance, information security incident management, business continuity management and compliance.

Analysts can be relatively confident that if organizations are ISO 17799 compliant that a high degree of information assurance is likely to be a characteristic of the data sets being used. The converse may be true.

Extracting, fusing and drawing conclusions based upon data bases with a low degree of information assurance may be wrought with all of the hazards that come from knowingly using bad data to make decisions. Using ISO/IEC 17799 as a baseline for information assurance can help mitigate these risks.

6241-07, Session 2

Personal privacy, information assurance, and the threat posed by Malware techology

M. R. Stytz, Institute for Defense Analyses; S. B. Banks, Calculated Insight

In spite of our best efforts to secure the cyber world, the threats posed to personal privacy by attacks upon networks and software continue unabated. While there are many reasons for this state of affairs, clearly one of the reasons for continued vulnerabilities in software is the inability to assess their security properties and test their security systems while they are in development. A second reason for this growing threat to personal privacy is the growing sophistication and maliciousness of malware coupled with the increasing difficulty of detecting malware. The pervasive threat posed by malware coupled with the difficulties faced when trying to detect its presence or an attempted intrusion make malware addressing the malware threat one of the most pressing issues that must be solved in order to insure personal privacy to users of the internet. In this paper, we will discuss the threat posed by malware, the types of malware found in the wild, and current techniques that are available for from a successful malware penetration. The final paper will contain an introduction, background section that includes a discussion of types of malware, discussion of anti-malware tools, and suggestions for future anti-malware efforts.

6241-08, Session 2

Energy efficient link layer security solution for wireless LANs

S. Ozdemir, Arizona State Univ.

For the last couple of years people have become too reliant on Wireless LAN (WLAN) for information exchange. As wireless technology has no inherent physical protection, WLANs introduce new serious security threats to the personal information of individuals and organizations. Unfortunately, much of the growth has not been accompanied with an appropriate level of security for most corporate networks. The broadcast nature of wireless networks promote casual eavesdropping of data traffic with possible security threats including unauthorized use of networks, and denial of service attacks etc. Therefore, as in any environment where data is transmitted over untreated media, in order to protect the data, certain safeguards must be in place and effectively managed. To this end, this paper introduces a wireless link layer security protocol for WLANs that provides the users of IEEE 802.11 WLAN a security level equivalent to the security level of wired networks. The proposed security protocol consists of three components: WLAN clients (STAs), WLAN Access Points (APs), and Authentication and Accounting Server (AAS). Before an STA can access the network, the user who uses the STA must be authenticated to the AP. And AP must be also authenticated to the STA so that there is no rogue AP in the network. Finally, the communication between STAs and APs, as well as between APs and AAS are protected and defended from any kind of interception, modification and fabrication. We performed extensive simulations to evaluate the security and energy consumption performance of the proposed security protocol. The cryptographic primitives are selected based on their security and power consumption to make proposed protocol scalable and a manageable solution for low power wireless clients, such as PDA.

6241-09, Session 2

Image sensor for security applications with on chip data authentication

P. Stifter, K. Eberhardt, A. Erni, K. C. Hofmann, AIM Infrarot-Module GmbH (Germany)

Sensors in a networked environment, which are used for security applications are jeopardized by man-in-the-middle and address spoofing attacks. By authentication and secure data transmission of the sensor's data stream, this can be thwart by fusing the image sensor with the necessary digital encryption and authentication circuit, which fulfils the three standard requirements of cryptography:

1. Data integrity 2. Authentication 3. Non-repudiation.

This paper presents the development done by AIM, which led to the unique sensor SECVGA, a high performance, monochrome (B/W), CMOS active pixel image sensor. The device captures still and motion images with a resolution of 800x600 active pixels and converts them into a digital data stream.

Additional to a standard imaging sensor, there is the capability of the on-chip cryptographic engine, to provide the authentication of the sensor to the host, based on a one-way authentication protocol. The protocol that has been realized, uses the exchange of a session-key to secure the following video data transmission. To achieve this, the calculation of the cryptographic checksum is done, which is obtained from the encrypted hash value of the complete image frame. The imager is equipped with an OTP-ROM, to give the capability to personalize it with a unique and unchangeable identity.

A two-wire I^2C compatible interface allows to program the functions of the imager, i.e. various operating modes, including the authentication procedure, the control of the integration time, the subframes of the pixel array and the frame rate.

6241-10, Session 2

Mining security events in Cougaar agent society

D. Dasgupta, J. M. Rodriguez, S. Balachandran, Univ. of Memphis

In distributed agent architecture, tasks are performed in multiple computers which are sometimes spread across different locations. While it is important to collect security critical sensory information from the agent society, it is equally important to analyze and report such security events in a precise and useful manner. Data mining techniques are found to be very efficient in the generation of security event profiles. This paper describes the implementation of such a security alert mining tool which generates profile of security events collected from a large agent society. In particular, our previous work addressed the development of a security

console to collect and display alert message (IDMEF) from a Cougaar (agent) society. These messages are then logged in a XML database for further off-line analysis. In our current work, stream mining algorithms are applied for sequencing and generating frequently occurring episodes, and then finding association rules among frequent candidate episodes. This alert miner could profile most prevalent patterns as indications of frequent attacks in a large agent society.

6241-11, Session 3

Distinguishing false from true alerts in Snort by data mining patterns of alerts

D. G. Schwartz, Florida State Univ.

Abstract not available.

6241-12, Session 3

A novel interacting multiple model-based network intrusion detection scheme

R. Xin, V. Venkatasubramanian, H. Leung, Univ. of Calgary (Canada)

The number of FBI computer network intrusion cases has doubled during each of the past two years forcing the network security industry to invent novel and robust intrusion detection and prevention systems. The current signature testing approach uses a database to record the intrusion patterns and the new intrusion signatures should be constantly updated. On the contrary, the anomaly based detection systems can discover new intrusions but were not favored compared to signature detection systems owing to their increased false alarms.

Anomaly detection is based on detecting an intrusion by carefully predicting some measure of the network traffic. The main source of the false alarm is the inaccuracy with which the traffic is modeled. Network traffic is seldom stationary. Our analysis of network traffic data from DARPA sites has indicated that they follow multiple models. The change in the traffic patterns can be attributed to the time of the day or day of the week. Owing to the non-stationary and multiple model (MM) nature of the network traffic, a multiple model predictor best models the network traffic.

In this paper, we propose and evaluate a novel anomaly based intrusion detection system using interacting multiple model detector. The interacting multiple model detector segments the network intrusion data based on their traffic patterns. The network intrusion is then identified by detecting large prediction errors. The proposed algorithm is applied to both host based and network based intrusion datasets obtained from Information Systems Technology Group (IST) of MIT Lincoln Laboratory, under Defense Advanced Research Projects Agency (DARPA ITO) and Air Force Research Laboratory (AFRL/SNHS). The performance of the proposed IMM based detector is compared with the conventional anomaly based detection schemes. Receiver operating characteristics (ROC) were evaluated using the DARPA and AFRL datasets to illustrate the improved detection performance of the IMM based anomaly detector over conventional anomaly based detectors.

6241-13, Session 3

Attribute selection using information gain for a fuzzy logic intrusion detection system

J. Gonzalez-Pino, J. Edmonds, M. Papa, Univ. of Tulsa

In the modern realm of information technology, data mining and fuzzy logic are often used as effective tools in the development of novel intrusion detection systems. This paper describes an intrusion detection system that effectively deploys both techniques and uses the concept of information gain to guide the attribute selection process.

The advantage of this approach is that it provides a computationally efficient solution that helps reduce the overhead associated with the data mining process. Experimental results obtained with a prototype system implementation show promising opportunities for improving the overall detection performance of our intrusion detection system.

6241-14, Session 3

Threshold-based clustering for intrusion detection systems

V. Nikulin, The Australian National Univ. (Australia)

Signature-based intrusion detection systems look for known, suspicious patterns in the input data. In this paper we explore compression of labeled empirical data using threshold-based clustering with regularization.

The main target of clustering is to compress training dataset to the limited number of signatures, and to minimize the number of comparisons that are necessary to determine the status of the input event as a result.

Essentially, the process of clustering includes merging of the clusters which are close enough.

As a consequence, we will reduce original dataset to the limited number of labeled centroids. In a complex with k-nearest-neighbor (kNN) method, this set of centroids may be used as a multi-class classifier.

The experiments on the KDD-99 intrusion detection dataset have confirmed effectiveness of the above procedure.

6241-15, Session 3

Distributed intrusion detection system based on fuzzy rules

P. Qiao, J. Su, C. Sun, Harbin Univ. of Science and Technology (China)

Computational intelligence is a well-established paradigm, where new theories with a sound biological understanding have been evolving. The intrusion detection systems have many of the characteristics of biological computers and many intelligent models can be built to perform a variety of tasks that are difficult or impossible to do with conventional computers. In a nutshell, which becomes quite apparent in light of the current research pursuits, the area is heterogeneous as being dwelled on such technologies as neurocomputing, fuzzy systems, probabilistic reasoning, artificial life, evolutionary algorithms, multi-agent systems etc. This paper is to give a design of computationally intelligent IDS incorporating evaluates fuzzy rule based classifiers to detect intrusions in a network. It first uses data mining techniques to process the network input data. Then by the using of genetic fuzzy and neuro-fuzzy in this model, self-organization, self-study and self-adaptation can be highly improved compared with other traditional intrusion detection systems. Experiment results reveal that the schemes evolving fuzzy neural networks could significantly reduce the false alarm rate while the attack detection rate remains high.

6241-16, Session 4

Mining emotional profiles using e-mail messages for earlier warnings of potential terrorist activities

B. Galitsky, Univ. of London (United Kingdom); B. Kovalerchuk, Central Washington Univ.

We develop a software system Text Scanner for Emotional Distress for helping to detect email messages which are suspicious of coming from people under strong emotional distress. It has been confirmed by multiple studies that terrorist attackers have experienced a substantial emotional distress at some points before committing a terrorist attack. Particularly, individuals who have run into certain problems in their life (such as broken relationships, frustration concerning the impact of a religion in a society, psychological problems, employment difficulties, etc.) have a higher likelihood to be approached by agents of terrorist networks, and

can be eventually participating in terrorist attacks. Therefore, if an individual with such distinguishing patterns can be detected on the basis of email texts, some preventive measures can be taken. Hence an early recognition of such patterns of emotional distress is crucial as it provides the earliest warning of potential future terrorist activity. An emotional profile is a formal representation of a sequence of emotional states through a textual discourse, where communicative actions are attached to these emotional states.

We develop the machine learning-based framework to find a number of emotional profiles, analyzed by an expert, which are similar to the given one. Scenarios are represented by directed graphs with labeled vertices (for communicative actions) and arcs (for temporal and causal relationships between these actions and their parameters). The proposed approach is applicable to a wide range of domains where mining for the attitudes of involved agents is crucial.

6241-17, Session 4

Detecting people of interest from internet data sources

R. A. Cardillo IV, D. M. Boulware, J. J. Salerno, Air Force Research Lab.

In previous papers, we have documented success in determining the key people of interest from a large corpus of real-world evidence. Our recent efforts are focused on exploring additional domains and data sources. Internet data sources such as email, web pages, and news feeds offer the ability to easily gather a large corpus of documents for various domains, but detecting people of interest in these sources introduces new challenges. Analyzing these massive sources magnifies entity resolution problems, and demands a storage management strategy that supports efficient algorithmic analysis and visualization techniques. This paper discusses the techniques we used in order to analyze the ENRON email repository, and to analyze several sets of web pages using our “Buddy” meta-search engine.

6241-18, Session 4

Web-based dynamic Delphi: a new survey instrument

J. Yao, Univ. of Regina (Canada)

We present a mathematical model for dynamic Delphi survey by taking advantages of Web technology. A comparative study on the performance of conventional Delphi and dynamic Delphi is conducted. It is suggested that the a dynamic Delphi survey may form a consensus quick. However, the result may not be robust due to the short-circus judgement issues.

6241-19, Session 4

Dimensional reduction of web traffic data

V. Nikulin, The Australian National Univ. (Australia)

Dimensional reduction may be effective in order to compress data without loss of essential information. Also, it may be useful in order to smooth data and reduce random noise. The model presented in this paper was motivated by the structure of the \textit{msweb} web-traffic dataset from the \textit{UCI} archive. It is proposed to reduce dimension (number of the used web-areas or \textit{vroots}) as a result of the unsupervised learning process maximizing specially defined average log-likelihood divergence. Two different web-areas will be merged in the case if these areas appear together frequently during the same sessions.

Essentially, roles of the web-areas are not symmetrical in the merging process. The web-area or \textit{cluster} with bigger weight will act as an attractor and will stimulate merging. In difference, the smaller cluster will try to keep independence. In both cases the powers of attraction or resistance will depend on the weights of the corresponding clusters. Above strategy will prevent creation of one super-big cluster, and will help to reduce number of non-significant clusters. The proposed method was illustrated using two synthetic examples. The first example is based on the ideal $vlink$ matrix which characterize weights of the $vroots$ and relations between them. The $vlink$ matrix for the second example was generated using specially designed web-traffic simulator.

6241-20, Session 5

A novel mark embedding and attack identifying technique for watermarking

W. Q. Lin, Huaqiao Univ. (China)

With the rapid growth of network distributions of information like image, there is an urgent need for copyright protection against pirating. As an effective method for ownership identification, digital watermarking technique arouses much interesting around the corresponding scientists. And much study is focused on information hiding technique. In this paper we propose a novel technique for watermarking. The technique was considered on other side of copyright protection: using mark when the watermark was embedded, if the watermarked image was attacked, we first identify the attack technique, and then take the corresponding method to lessen or remove the effect of attack. As a result satisfactory extracted watermark can be obtained.

The principle of this technique is as follow: in sub-band LH and HL of wavelet coefficient, it shown a good performance in anti-clipping attack, but it can not resist the attack caused by adding noise, filtering, JPEG compressing and etc. So if we embedding a known sequence as the mark in these bands, when watermark is extracted, we can judge what kinds of attack and the damage degree that the watermarked image had suffered by detecting the known sequence.

Usually the bit length of mark sequence is much smaller than the pixel number in the sub-band, and the mark sequence is also scrawled by spread spectrum code. So it is considerably powerful in resisting the clipping operation. This means the estimation of the attack type may be considerably accurate. Therefore the algorithm has the merit of robustness, strong anti-attack ability and security.

6241-21, Session 5

Broad frequency acoustic response of ground/floor to human footsteps

A. E. Ekimov, J. M. Sabatier, The Univ. of Mississippi

The human footstep is one of several signatures that can serve as a useful parameter for human detection. In early research, the force of footsteps was measured on load cells and the input energy from multiple footsteps was detected in the frequency range of 1-4 Hz. Cress investigated the seismic velocity response of outdoor ground sites to individuals that were crawling, walking, and running [D. H. Cress, “Terrain considerations and data base development for the design and testing of devices to detect intruder-induced ground motion,” U.S. Waterways Experimental Station; Technical report- U.S. Army Engineer Waterways Experiment Station; M-78-1)]. In this work, the seismic velocity response was shown to be site-specific and the characteristic frequency range was 20-90 Hz. The current paper will report on vibration and sound pressure responses of human footsteps in a broad frequency range. The low frequency vibration and sound components are well known in the literature and generated by the force component normal to the ground/floor. This force is a function of person’s weight and a manner of motion (walking, running). Forces tangential to the ground/floor from footstep and the ground reaction generate the high frequency components of human footsteps. The interactions of these two forces produce the sliding contacts between foot and ground/floor and the result of this rubbing is a friction noise. The parameters of this friction noise, such as frequency band and vibration and sound magnitudes as functions of walking style, were studied. The results of tests are presented and discussed.

6241-22, Session 5

Toward a threat model for group communications

J. L. Hester, W. J. Yurcik, Univ. of Illinois at Urbana-Champaign

The importance of group communications and the need to efficiently and reliably support it across a network is a very important issue for the next decade. New group communication services are emerging such multimedia conferencing/groupware, distributed interactive simulations, sensor fusion systems, command and control centers, and on-demand entertainment. While a succession of point-to-point unicast routes could provide group communications, this approach is inherently inefficient and unlikely to support the increased resource requirements of these new services.

There is the lack of a comprehensive process to designing security and survivabilty into group communications schemes.

Designing such protection for group communications is best done by utilizing proactive system engineering rather than reacting with ad hoc countermeasures to the latest attack du jour.

Threat modeling is the foundation for secure system engineering processes because it organizes system threats and vulnerabilities into general classes so they can be addressed with known protection techniques. Although there has been prior work on threat modeling primarily for software applications, to our knowledge this is the first attempt at domain-specific threat modeling for group communications.

We discuss protection challenges unique to group communications and propose two different processes to creating a threat model for group communications: one based on classical security principles (Confidentiality, Integrity, Availability, Authentication, or CIAA) and another based on the Data Lifecycle Model. It is our hope that this initial work will start a discussion on how to better design and implement protection solutions against threats to group communications.

6241-23, Session 5

AutoCorrel: a neural network event correlation approach

M. G. Dondo, Defence Research and Development Canada (Canada); N. Japkowicz, R. D. Smith, Univ. of Ottawa (Canada)

Intrusion detection analysts are usually swamped by multitudes of alerts originating from the many installed intrusion detection systems (IDS) on their networks. Properly managing these alerts and correlating them to previously seen threats is critical in the ability to effectively protect a network from attacks. Manually correlating events is a slow tedious task prone to human error. We present a two-stage alert correlation approach involving an artificial neural network (ANN) autoassociator and a single parameter decision threshold-setting unit. By clustering closely matched alerts together, this approach would be beneficial to the analyst. In this approach, alert attributes are extracted from each alert content and used to train an autoassociator. Based on the reconstruction error determined by the autoassociator, closely matched alerts are grouped together. Whenever a new alert is received, it is automatically categorised into one of the alert clusters which identify the type of attack and its severity level as previously known by the analyst. If the attack is entirely new and there is no match to the existing clusters, this would be appropriately reflected to the analyst. There are several advantages to using an ANN based approach. First, ANNs acquire knowledge straight from the data without the need for a human expert to build sets of domain rules and facts. Second, once trained, ANNs are very fast and quite good for near real-time applications. Finally, while learning, ANNs perform a type of dimensionality reduction allowing a user to input large amounts of information without fearing an efficiency bottleneck. Thus, rather than storing the data in TCP Quad format and performing a multi-stage query on insufficient information, the user can input all the relevant information available and allow the neural network to organise and reduce this knowledge in an adaptive and goal-oriented fashion.

6241-25, Session 5

Data modeling for predictive behavior hypothesis formation and testing

H. M. Jaenisch, dtech Systems Inc.; J. W. Handley, SPARTA, Inc.; M. Barnett, Computer Sciences Corp.; D. A. Grover, Washington Square Associates, Inc.

This paper presents a novel framework based on DANCER and QUEST, which enables dictionary free word recognition and meaning assignment to be done using analytical equation derivation and testing. In this next phase of our work, we take the Data Models derived for associated words from the relationship matrix and form stimulus and resulting descriptions as word lists for who, where, when, what, how and why. Each example yields a classical control theory transfer function model of associated behavior against which new evidence can be tested to see if the expected hypothesis is supported. Additionally, the model can be solved to yield conjectured results with varying confidences. The analytical model may also be inverted for what-if analysis by seeding the expected scenario results and solving for the required input factors. This forms a unique and powerful framework bringing powerful Data Model Predictive Control Theory analytical tools to bear on a traditional ad hoc and heuristic problem.

6241-27, Session 6

Reliance on perimeter security

K. Kumpf, SSH Communications Security, Inc.

It was Pogo who said, “We have met the enemy and he is us.” This statement was never more true than in the case of enterprise IT security. According to Gartner, 70 percent of unauthorized access to information systems is committed by employees and over 95 percent of these internal security breaches result in significant financial losses. For these reasons, traditional perimeter security supplied by systems such as firewalls and anti-virus software are no longer sufficient for protecting the enterprise.

End-to-end communications security is a new approach that overcomes the limitations of today’s enterprise security approaches for protecting data communications from start to finish. Operating between the applications and the IT infrastructure, this concept of end-to-end security provides central manageability for both security software and policies across the enterprise, and delivers an order of magnitude improvement in security against both internal and external risks.

Kevin Kumpf, Senior Sales Engineer, will discuss the inherent limitations of existing enterprise security approaches and will outline the key elements of an end-to-end IT infrastructure, highlighting the tremendous security benefits this approach offers enterprises of all types.

6241-28, Session 6

Extending key sharing: how to generate a key tightly coupled to a network security policy

M. I. Kazantzidis, Broadata Communications, Inc.

The GIG is envisioned to connect millions of geographically distributed computers connected through wired, wireless, mobile, ad-hoc or other mission networks. A secure and robust network-centric environment is necessary to achieve information superiority. Current state of the art security policy technologies, besides the small scale limitation and largely manual nature of accompanied management methods, are lacking a) in real-timeliness of policy implementation and b) vulnerabilities and inflexibility stemming from the centralized policy decision making; even if, for example, a policy description or access control database is distributed, the actual decision is often a centralized action and forms a system single point of failure. In this paper we are presenting a new way to implement any security policy by a systematic and efficient key distribution procedure. Specifically, we extend the polynomial Shamir key splitting into an easily deployable key generation procedure that results a single key per

entity that "knows" its role in the specific access control policy from which it was derived. The system is considered efficient as it can be used to avoid expensive PKI operations or pairwise key distributions as well as provides superior security due to its distributed nature, the fact that the key is tightly coupled to the policy, and that policy change may be implemented in minutes rather than hours or days.

6241-29, Session 6

A novel unsupervised anomaly detection based on robust principal component classifier

W. Qiu, Y. Wu, Chongqing Univ. of Posts and Telecommunication (China)

New-type intrusion activities appear increasingly and most of them are not detected automatically by kinds of computer security systems. Some intelligent theories[1,2]P are applied to network security fields, such as neural network and genetic algorithm. Nowadays anomaly detection methods based on these theories have played important roles in network security fields. However, these methods are highly sensitive to outliers. The presence of mislabeled data can result in highly nonlinear decision surface and over-fitting of training set, which leads to poor generalization ability and classification accuracy. Hence, IDSs need a mass of labeled data in the training process, which hampers the application and popularity of traditional IDSs.

Principal component analysis (PCA) has proven to be an exceedingly effective technique for dimensionality reduction. Its many application areas include data compression, image analysis, pattern recognition, etc. Principal component classifier (PCC) has firstly been applied to anomaly detection in "A Novel Anomaly Detection Scheme Based on Principal Component Classifier"P, which is creative; However, the method still has the drawback of over-fitting of training set. To solve the over-fitting problem, this paper proposes a novel anomaly detection scheme based on robust principal component classifier (RPCC). The goal of robust PCA (RPCA) methods is to obtain principal components that are not influenced much by outliers. An anomaly detection model is constructed from the distance in the principal component space and the reconstruction error of training data. The experiments show that this model can detect network intrusions, especially unknown intrusions with relatively low false positive rate.

The contribution of the paper is two-fold. First, this paper develops a framework for anomaly detection model based on RPCC by addressing the above over-fitting of training samples contaminated by outliers in "A Novel Anomaly Detection Scheme Based on Principal Component Classifier" Second, this paper develops a new anomaly detection classifier based on the reconstruction error, which can improve the detection rate of intrusions, especially unknown intrusions.

6241-30, Session 6

AINIDS: an immune-based network intrusion detection system

Q. Yan, Tsinghua Univ. (China)

Intrusion detection can be looked as a problem of pattern classification. Since intrusion detection has some intrinsic characteristic such as high dimensional feature spaces, linearity non-differentiation, severe unevenness of normal pattern and anomaly pattern, it is very difficult to detection intrusions directly by use of classical pattern recognition method. Nature immune system is a self-adaptive and self-learning classifier, which can accomplish recognition and classification by learning, remembrance and association. First we use four-tuple to define nature immune system and intrusion detection system, then we give the mathematic formalization description of performance index of intrusion detection system. Finally we design and develop an immune-based network intrusion detection system— AINIDS, which includes a data collector component, a packet head parser and feature extraction component, antibody generation and antigen detection component, co-stimulation and report component and rule optimization component. The antibody generation and antigen detection component is the key module of AINIDS. In the component the passive immune antibodies and the automatic immune antibodies that include memory automatic immune antibodies and fuzzy automatic immune antibodies are proposed by analogy with natural immune system. The passive immune antibodies inherit available rules and can detect known intrusion rapidly. The automatic immune antibodies integrate statistic method with fuzzy reasoning system to improve the detection performance and can discover novel attacks. AINIDS is tested by the data that we collect from our LANs and by the data from 1999 DARPA intrusion detection evaluation data sets. Both experiments prove AINIDS has good detection rate for old and novel attacks.

6241-31, Session 7

Clustering method via independent components for semi-structured documents

T. Wang, D. Liu, Harbin Engineering Univ. (China)

This paper presents a novel clustering method for XML documents. Much research effort of document clustering is currently devoted to support the storage and retrieval of large collections of XML documents. However, traditional text clustering approaches cannot process the structural information of semi-structured documents. Our technique is firstly to extract relative path features to represent each document. And then, we transform these documents to Structured Link Vector Model (SLVM) and propose a similarity computation. Different from VSM, which is used to represents document in traditional method, SLVM can be considered as an extended vector space model for semi-structured representation. Before clustering, we apply Independent Component Analysis (ICA) to reduce dimensions of VSM. To the best of author's knowledge, ICA has not been used for XML clustering. The C-means partition algorithm is also improved: When a solution can be no more improved, the algorithm makes the next iteration after an appropriate disturbance on the local minimum solution. Thus the algorithm can skip out of the local minimum and in the meanwhile, reach the whole search space. Experimental results based on two real datasets and one synthetic dataset, show that the proposed approach is efficient, and outperforms naïve-clustering method without ICA.

6241-32, Session 7

Mining hospital management data

S. Tsumoto, Shimane Univ. (Japan)

Rapid progress in information technology has come to enable us to store all the information in a hospital information system, including management data, patient records, discharge summary and laboratory data. Although the reuse of those data has not started, it has been expected that the stored data will contribute to analysis of hospital management. In this paper, the discharge summary of Chiba University Hospital, which has been stored since 1980's were analyzed to characterize the university hospital. The results show several interesting results, which suggests that the reuse of stored data will give a pow erful tool to support a long-period management of a university hospital.

6241-33, Session 7

Visualization of similarities and dissimilarities in rules using MDS

S. Tsumoto, Shimane Univ. (Japan)

One of the most important problems with rule induction methods is that it is very difficult for domain experts to check millions of rules generated from large datasets. The discovery from these rules requires deep interpretation from domain knowledge.

Although several solutions have been proposed in the studies on data mining and knowledge discovery, these studies are not focused on similarities between rules obtained. When one rule r_1 has reasonable features and the other rule r_2 with high similarity to r_1 includes unexpected factors, the relations between these rules will become a trigger to the discovery of knowledge.

In this paper, we propose a visualization approach to show the similar and dissimilar relations between rules based on multidimensional scaling, which assign a two-dimensional cartesian coordinate to each data point from the information about similiaries between this data and others data.

We evaluated this method on two medical data sets, whose experimental results show that knowledge useful for domain experts could be found.

6241-34, Session 7

Damage assessment of mission essential buildings based on simulation studies of low-yield explosives

T. G. L. Allen, Air Force Research Lab.

Mitigating the threat of terrorist attacks against high occupancy buildings essential to the mission of an organization is a challenging task. At the same time, it is difficult to predict how, why, and when terrorists may attack these assets. Many factors must be considered in creating a safe building environment. Although it is possible that the dominant threat mode may change in the future, bombings have historically been a favorite tactic of terrorists. Ingredients for homemade bombs are easily obtained on the open market, as are the techniques for making bombs. Bombings are easy and quick to execute. In this study, we examine the placement of bombs near doorways of buildings using the shock wave simulation code CTH and examine the damage effects on the interior of the building, particularly the damage that is incurred on a computer center and personnel. These simulation experiments provide data on the effectiveness of a building's security and an understanding of the phenomenology of shock waves as they propagate through rooms and corridors. Visualizations from this analysis are used to understand the complex flow of the airblasts around corridors and hallways. Finally, we make suggestions for improving the defense of a building against such terrorist attacks.

6241-36, Poster Session

A noise-immune cryptographic information protection method for facsimile information transmission and the realization algorithms

V. G. Krasilenko, Open International Univ. of Human Development (Ukraine); V. F. Bardachenko, Institute of Cybernetics (Ukraine); A. I. Nikolsky, A. A. Lazarev, K. V. Ogorodnik, Vinnitsa State Technical Univ. (Ukraine)

At first we will analyse the existent methods of cryptographic defence for the facsimile information transfer, we will consider their shortcomings and prove the necessity of better information protection degree. Farther we will stop on the method of information protection that is based on presentation of input data as images. We offer a new noise-immune algorithm for realization of this method which consists in transformation of an input frame by pixels transposition according to an entered key. At decoding reverse transformation of image with the use of the same key is used.

Practical realization of the given method takes into account noise in the transmission channels and information distortions by scanners, faxes and others like that. We will show that the given influences are reduced to the transformation of the input image coordinates. Then we will show tne algorithm in detail and consider its basic steps. We will show the possibility of the offered method by the means of the developed software. We will describe the realized algorithm which corrects curvature of frames: turn, scaling, fallout of pixels and others like that. We will show that at a low noise level (loss of pixel information less than 10 percents) it is possible to encode, transfer and decode any types of images and 12 size of font character texts by the software. The software filters for information restore and noise removing allow to transfer fax data with 30 percents pixels loss at 18 font size of text. We will show that this percent of data loss can be considerably increased by the use of the software character recognition block, that is realized by fuzzy-neural algorithms. We will make examples of the coded and decoded images and texts. Finally we will show the basic results of the work and outline the most perspective ways for improvement of the algorithm and the cryptographic information protection method.

6241-37, Poster Session

The design and application of data warehouse during modern enterprises environment

L. Zhou, C. Liu, Capital Normal Univ. (China); C. Wang, Harbin Engineering Univ. (China)

The interest in analyzing data has grown tremendously in recent years. To analyze data, a multitude of technologies is need, namely technologies from the fields of Data Warehouse, Data Mining, On-line Analytical Processing (OLAP). This paper proposes the system structure models of the data warehouse during modern enterprises environment according to the information demand for enterprises and the actual demand of user's , and also analyses the benefit of this kind of model in practical application, and provides the setting-up course of the data warehouse model. At the same time it has proposes the total design plans of the data warehouses of modern enterprises. The data warehouse that we build in practical application can be offered: high performance of queries; efficiency of the data; independent characteristic of logical and physical data. In addition, A Data Warehouse contains lots of materialized views over the data provided by the distributed heterogeneous databases for the purpose of efficiently implementing decision-support, OLAP queries or data mining. One of the most important decisions in designing a data warehouse is selection of right views to be materialized. In this paper, we also have designed algorithms for selecting a set of views to be materialized in a data warehouse. First, we give the algorithms for selecting materialized views. Then we use experiments do demonstrate the power of our approach. The results show the proposed algorithm delivers an optimal solution. Finally, we discuss the advantage and shortcoming of our approach and future work.

6241-39, Poster Session

A practical timing attack on RSA over a LAN

M. J. Lodato, I. I. Jouny, Lafayette College

Today, the specific implementation of a cryptosystem is of possibly greater importance than the underlying cryptographic algorithm itself. Through side-channel cryptanalysis, an adversary may deduce a secret key just by monitoring implementation-specific side channels, such as execution time or power consumption during a cryptographic operation. In this paper, we describe a successful remote timing attack against a server running SSL. Using a modified chosen-ciphertext attack on Chinese Remaindering Theorem (CRT) implementations of RSA, we show it is practical to recover a 1024-bit key in under an hour over a local area network. Additionally, we derive a mathematical analysis of the attack and then offer possible countermeasures.

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6242-01, Session 1

Multisource evidence fusion for cyber-situation assessment

B. Sabata, Aginova Inc.; C. J. Ornes, IET, Inc.

Novel methods of detecting cyber attacks on networks have been developed that are able to detect an increasing diverse variety of malicious cyber-events. However, this has only resulted in additional information burden on the network analyst. The integration of the distributed evidence from multiple sources is missing or ad-hoc at best. Only with the fusion of the multi-source evidence can we reason at a higher semantic level to detect and identify attacks and attackers. Further, integration at a higher semantic level will reduce the cognitive load on the security officer and will make it possible for reasonable responses. This paper presents an overview of the D-Force system that uses a Bayesian Evidential Framework for fusing the multi-source evidence in a network to detect and recognize attacks. Attack hypothesis are generated as a result of evidence at the different network and host sensors. The hypotheses are verified or denied with additional evidence. Based on our initial experiments and tests the D-Force system promises to be a powerful tool in the information security officer's arsenal.

6242-02, Session 1

Combining elements of information fusion and knowledge-based systems to support situation analysis

J. Roy, Defence Research and Development Canada (Canada)

Situation awareness has emerged as an important concept in military and public security environments. Situation analysis is defined as a process, the examination of a situation, its elements, and their relations, to provide and maintain a product, i.e., a state of situation awareness for the decision maker(s). It is well established that information fusion, defined as the process of utilizing one or more information sources over time to assemble a representation of aspects of interest in an environment, is a key enabler to meeting the demanding requirements of situation analysis. However, although information fusion is important, developing and adopting a knowledge-centric view of situation analysis should provide a more holistic perspective of this process. This is based on the notion that awareness ultimately has to do with having knowledge of something. Moreover, not all of the situation elements and relationships of interest are directly observable. Those aspects of interest that cannot be observed must be inferred, i.e., derived as a conclusion from facts or premises, or by reasoning from evidence. This paper discusses aspects of knowledge, and how it can be acquired from experts, formally represented and stored in knowledge bases to be exploited by computer programs, and validated. Knowledge engineering is reviewed, with emphasis given to cognitive and ontological engineering. Facets of reasoning are discussed, along with inferencing methods that can be used in computer applications. Finally, combining elements of information fusion and knowledge-based systems, an overall approach and framework for the building of situation analysis support systems is presented.

6242-03, Session 1

Rule-based situation assessment for sea surveillance

J. Edlund, M. Grönkvist, A. Lingvall, E. Sviestins, Saab Systems (Sweden)

In order to achieve greater situation awareness it is necessary to identify relations between individual entities and their immediate surroundings, neighbouring entities and important landmarks. The idea is that long-term intentions and situations can be identified by patterns of more rudimentary behaviour, in essence situations formed by combinations of different basic relationships. In this paper we present a rule based situation assessment system that utilises both COTS and in-house software. It is built upon an agent framework that speeds up development times, since it takes care of many of the infrastructural issues of such a communication intense application as this is, and a rule based reasoner that can reason about situations that develop over time. The situation assessment system is developed to be simple, but structurally close to an operational system, with connections to outside data sources and graphical editors and data displays. It is developed with a specific simple Sea-surveillance scenario in mind, which we also present, but the ideas behind the system are general and are valid for other areas as well.

6242-04, Session 1

Realizing situation awareness within a cyber environment

G. P. Tadda, J. J. Salerno, D. M. Boulware, M. L. Hinman, Air Force Research Lab.; S. Gorton, Skaion Corp.

Situation Awareness (SA) problems all require an understanding of current activities, an ability to anticipate what may happen next, and techniques to analyze the threat or impact of current activities and predictions. These processes of SA are common regardless of the domain and can be applied to the detection of cyber attacks. This paper will describe the application of a SA framework to implementing Cyber SA, describe some metrics for measuring and evaluating systems implementing Cyber SA, and discuss ongoing projects in this area. We conclude with some ideas for future activities.

6242-05, Session 1

Measuring situational awareness and resolving inherent high-level fusion obstacles

M. Sudit, SUNY/Univ. at Buffalo; A. D. Stotz, Calspan-UB Research Ctr., Inc.; M. Holender, SUNY/Univ. at Buffalo

Information Fusion Engine for Real-time Decision Making (INFERD) is a tool that was developed to supplement current graph matching techniques in Information Fusion problems. Based on sensory data and a priori models, INFERD dynamically generates, evolves, and evaluates hypothesis on the current state of the environment. The a priori models developed are hierarchical in nature lending them to a multi-level Information Fusion process whose primary output provides a situational awareness of the environment of interest in the context of the models running. In this paper we look at INFERD's multi-level fusion approach and provide insight on the inherent problems such as fragmentation in the approach and the research being undertaken to mitigate those deficiencies.

Due to the large variance of data in disparate environments, the awareness of situations in those environments can be drastically different. To accommodate this, the INFERD framework provides support for plug-and-play fusion modules which can be developed specifically for domains of interest. However, because the models running in INFERD are graph based, some default measurements can be provided and will be discussed in the paper. Among these are a Depth measurement to determine how much danger is presented by the action taking place, a Breadth measurement to gain information regarding the scale of an attack that is currently happening, and finally a Reliability measure to tell the user how credible the information in the template is.

6242-06, Session 2

Intent inference for attack aircraft through fusion

G. W. Ng, K. H. Ng, R. Yang, DSO National Labs. (Singapore); P. H. Foo, National Univ. of Singapore (Singapore)

Intent inference is about analyzing the actions and activities of an adversarial force or target of interest to reach a conclusion (prediction) on its purpose. In this paper, we report one of our research works on intent inference to determine the likelihood of an attack aircraft being tracked by a military surveillance system delivering its weapon. Effective intent inference will greatly enhance the defense capability of a military force in taking preemptive action against potential adversaries. It serves as early warning and assists the commander in his decision making. For an air defense system, the ability to accurately infer the likelihood of a weapon delivery by an attack aircraft is critical. It is also important for an intent inference system to be able to provide timely inference. We propose a solution based on the analysis of flight profiles for offset pop-up delivery. Simulation tests are carried out on flight profiles generated using different combinations of delivery parameters. In each simulation test, the state vectors and the measurement vectors of the tracked aircraft are updated via the application of the Interacting Multiple Model filter. Relevant variables of the filtered track (flight trajectory) are used as inputs to a Mamdani-type fuzzy inference system. The output produced by the fuzzy inference system is the inferred possibility of the tracked aircraft carrying out a pop-up delivery. We present experimental results to support our claim that the proposed solution is indeed feasible and also provides timely inference that will assist in the decision making cycle.

6242-07, Session 2

Higher-level fusion for military operations based on abductive inference: proof of principle

A. V. Pantaleev, J. R. Josephson, The Ohio State Univ.

This research is part of a proposed shift in emphasis in decision support from optimality to robustness. Computer simulation is emerging as a useful tool in planning courses of action (COAs). Simulations require domain models, but there is an inevitable gap between models and reality - some aspects of reality are not represented at all, and what is represented may contain errors. As models are aggregated from multiple sources, the decision maker is further insulated from model weaknesses. To realize the full power of computer simulation to decision making, decision support systems should support the planner in exploring the robustness of COAs with respect to various aspects of the simulation models.

This paper demonstrates a method of exploring the robustness of a COA with respect to specific assumptions embedded in the model about whose accuracy the decision maker might have concerns. The domain is that of peacekeeping in a country where three different demographic groups coexist in tension. An external peacekeeping force strives to achieve stability, better economy, and higher degree of democracy in the country. A proposed COA for such a force is simulated multiple times while varying the assumptions. A visual data analysis environment is used as a high-performance tool for COA robustness exploration. The aim is to help the decision maker choose a COA that is likely to be successful even in the face of potential errors in the assumptions in the models.

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6242-08, Session 2

Fusing terrain and goals: agent control in urban environments

V. Kaptan, E. Gelenbe, Imperial College London (United Kingdom)

The changing face of contemporary military conflicts has forced a major shift of focus in tactical planning and evaluation from the classical Cold War battlefield to an asymmetric guerrilla-type warfare in densely populated urban areas. The new arena of conflict presents unique operational difficulties due to factors like complex mobility restrictions and the necessity to preserve civilian lives and infrastructure. In this paper we present a novel method for autonomous agent control in an urban environment. Our approach is based on fusing terrain information and agent goals for the purpose of transforming the problem of navigation in a complex environment with many obstacles into the easier problem of navigation in a virtual obstacle-free space.

The main advantage of our approach is its ability to act as an adapter layer for a number of efficient agent control techniques which normally show poor performance when applied to an environment with many complex obstacles. Because of the very low computational and space complexity at runtime, our method is also particularly well suited for simulation or control of a huge number of agents (military as well as civilian) in a complex urban environment where traditional path-planning may be too expensive or where a just-in-time decision with hard real-time constraints is required.

6242-09, Session 2

Hybrid methods for multisource information fusion and decision support

J. J. Braun, Y. Glina, MIT Lincoln Lab.

Automatic decision-support tasks often involve multiple information sources that are potentially exploitable in the decision-making process. In some important applications, the data provided by the multiple sources can be uncertain, inconsistent, incomplete, conflicting, and ambiguous. Fusion of and decision-making from such data is particularly challenging, especially in situations where the domain phenomena cannot be modeled adequately due to an insufficient a priori knowledge. Our ongoing research program addresses multisource information fusion and decision-making in these challenging conditions. The application context is that of multisensor systems for biological attack detection and characterization, however the methods discussed in the paper are applicable also to other sensing domains and higher-level tasks such as battlespace management. The sources of data may include a variety of disparate sensors, point and standoff, as well as information sources other than sensors.

This paper discusses the progress of this ongoing research, in particular in the area of the machine-intelligence based decision-support architecture termed FLASH (Fusion, Learning, Adaptive Super-Hybrid) we have proposed previously. The cognitive-processing orientation and the hybrid nature, including multiple machine-learning and approximate reasoning paradigms, such as Support Vector Machines, Hidden Markov Models, feedforward neural networks, fuzzy ARTMAPs, and Dempster-Shafer theory, are amongst the highlights of FLASH. Selected specifics of the FLASH internals, such as its feature selection techniques, supervised and unsupervised learning, clustering, and recognition facilities, are discussed. The results to date are presented. These include the background type determination and bioattack detection computational experiments using data obtained with a multisensor fusion testbed we have also developed. The efficacy of selected methods of FLASH, such as the supervised learning techniques of FLASH, the unsupervised ARTMAP-based techniques for the determination of multiple background classes, and techniques for integration of these components, is discussed. Issues related to the processing of information originating from sources other than sensors, such as human language declarations or opinions, and coping with the imprecision and vagueness of such data, are considered. Finally, the paper discusses applicability of FLASH and its methods to the high-level

fusion and reasoning for complex battlespace management problems such as situational awareness and the course-of-action decision support.

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6242-10, Session 2

Classifiers and distance-based evidential fusion for road travel time estimation

N. El Faouzi, Institut National de Recherche sur les Transports (France); E. Lefevre, Univ. d'Artois (France)

This paper addresses the road travel time estimation on an urban axis by classification method based on evidence theory. The travel time (TT) indicator can be used either for traffic management or for drivers' information. The information used to estimate the travel time (induction loop sensor, cameras, probe vehicle,...) is complementary and redundant. It is then necessary to implement strategies of multi-sensors data fusion. The selected framework is the evidence theory. This theory takes more into account the imprecision and uncertainty of multisource information. Two strategies were implemented. The first one is classifier fusion where each information source, was considered as a classifier. The second approach is a distance-based classification for belief functions modelling. Results of these approaches, on data collected on an urban axis in the South of France, show the outperformance of fusion strategies within this application.

6242-11, Session 3

CommonSense: a preprocessing system to identify errors in large transcribed corpora

R. Propper, K. Mohajer, V. R. Pratt, Stanford Univ.

A system was designed to locate and correct errors in large transcribed corpora. The program, called CommonSense, relies on a set of rules that identify mistakes related to homonyms, words with distinct definitions but identical pronunciations. The system was run on the 1996 and 1997 Broadcast News Speech Corpora, and correctly identified more than 400 errors in these data. Future work may extend CommonSense to automatically correct errors in hypothesis files created as the output of speech recognition systems.

6242-12, Session 3

Pedestrian detection by multisensor fusion in surveillance

Y. Ma, Honeywell Technology

Automated surveillance technology has made some significant initial steps towards assisting the human operator perform some basic security functions such as: motion detection and object tracking. However, there are two problems that need to be addressed further, if the systems are going to become widely accepted in the market place. First, High False Alarm Rates - Current surveillance systems work well only under a narrow range of operational parameters. However most applications especially outdoors, require a wide range of operation and this causes current surveillance systems to fail due to high false alarm rate and/or frequent misses of the objects of interest. The operator will then turn it off, because the system cannot be "trusted". Second, severely affected by Lighting Conditions and Weather - Future surveillance systems must be able to operate in a 24/7 mode. Most security concerns are at night in not well lit or not at all lit places. Weather is also a major factor for outdoor applications. Surveillance systems must be hardened against a wide range of weather conditions. Accordingly, at Honeywell Labs, we have developed a Multi-spectral system which collects collocated data in four spectral bands: visible, near IR (reflective), mid-wave IR (3-5 μm thermal), and long-wave IR (8-14 μm thermal). This allows us to determine more exhaustive information for all objects of interest. e.g. thermal features, such as the signature of a running engine in a vehicle, are not found in the visible spectrum and vice-versa some problems in the visible domain such as the shadow of a moving object, disappear in the thermal domain.

In this paper, we present multi-sensor (Multi-spectral) fusion to perform pedestrian detection. The benefit can increase the robustness of the low level algorithms. e.g. reduced false alarm rate, and/or extend the operational range of the system. Our fusion method is presented to combine detection results in the visible images and the thermal images. Commonly, the motion detection results in the visible images are easily affected by noise and shadow. The objects in the thermal image are relative stable, but they may lose some parts of the objects. We will determine which detected part should be preserved and which part should be deleted. This is the objective of fusion. Three rules are brought forward to reach the goal. The first one is the continuity rule. If an object is detected as a whole in one video, its corresponding object in another video is also considered to be a continuous one. Then the separate parts of the object will be linked in the video. The second is hole rule. If there are holes in the detected object in one video, whereas no related holes in another video, the holes need to be filled. The third one is the sunken part rule. Some lost part on the detected parts in one video may be on the boundary of the object, we need to judge if the part is a sunken part or not. If so, the sunken part should be filled. The fusion will give a good pedestrian detection result, but it also may lose some small object parts. As the post-processing step, the level set method will give the detection result a refined boundary. We will use real data collected at Honeywell labs' parking lot to demonstrate the effectness of our proposed methods.

6242-13, Session 3

Feature extraction and fusion for protein structure identification in cryo-electron microscopic images

V. R. Riasati, Science Applications International Corp.

In this paper we utilize the Projection-Slice Synthetic Discriminant Function Filters, PSDF, developed with maximum energy projections in concert with a component analysis technique to simultaneously reduce the data set that represents each of the training images and to emphasize subtle differences in each of the training images. These differences are encoded into a fused image using the PSDF approach in order to improve the feature sensitivity for the recognition and identification of protein images formed from a cryo-electron microscopic imaging process. The PSDF and component analysis provide a premise not only for the identification of the class of structures under consideration, but also for detecting the orientation of the structures in these images. The protein structures found in cryo-electron microscopic imaging represent a class of objects that have low resolution and contrast and subtle variation. This poses a challenge in design of filters to recognize these structures due to false targets that often have similar characteristics as the protein structures. The incorporation of a component analysis, Gaussian-component dependency removal, and eigen values conditioning, in forming the filter provides an enhanced approach of decorrelating features and images prior to their incorporation into a fused reference image. We present our method of fusion and the results of the application of this approach to a protein structure recognition problem.

6242-14, Session 3

Prediction of adverse outcomes of acute coronary syndrome using intelligent fusion of triage information with HUMINT

C. L. McCullough, A. J. Novobilski, F. Fesmire, The Univ. of Tennessee at Chattanooga

Faculty from the University of Tennessee at Chattanooga and the University of Tennessee College of Medicine, Chattanooga Unit, have used data

mining techniques to examine a set of fourteen features, data items, and HUMINT assessments for 2,148 emergency room patients with symptoms possibly indicative of Acute Coronary Syndrome. Specifically, the authors have generated Bayesian networks describing linkages and causality in the data, and have compared them with neural networks. The data includes objective information routinely collected during triage and the physician's initial case assessment, a HUMINT appraisal. Both the neural network and the Bayesian network were used to fuse the disparate types of information with the goal of forecasting thirty-day adverse patient outcome. This paper presents details of the methods of data fusion including both the data mining techniques and the neural network. Results are compared using Receiver Operating Characteristic curves describing the outcomes of both methods, and these are compared in terms of both specificity and sensitivity with the attending physician's initial case assessment of symptoms. While preliminary, the results of this continuing study are significant both from the perspective of potential use of the intelligent fusion of biomedical informatics to aid the physician in prescribing treatment necessary to prevent death or other serious adverse outcome from ACS and as a model of fusion of objective data with subjective HUMINT assessment. Possible future work includes extension of successfully demonstrated intelligent fusion methods to other medical applications, and use of decision level fusion to combine results from data mining and neural net approaches with the physician's assessment for even more accurate outcome prediction.

6242-15, Session 4

Target tracking for unattended ground sensors employing distributed cluster management

C. A. Stelzig, M. A. Essawy, General Dynamics Advanced Information Systems; S. Minor, U.S. Army Night Vision & Electronic Sensors Directorate

Interest in the distribution of processing in unattended ground sensing (UGS) networks has resulted in new technologies and system designs targeted at reduction of communication bandwidth and resource consumption through managed sensor interactions. A successful management algorithm should not only address the conservation of resources, but also attempt to optimize the information gained through each sensor interaction so as to not significantly deteriorate target tracking performance.

This paper investigates the effects of Distributed Cluster Management (DCM) on tracking performance when operating in a deployed UGS cluster. Originally designed to reduce communications bandwidth and allow for sensor field scalability, the DCM has also been shown to simplify the target tracking problem through reduction of redundant information. It is this redundant information that in some circumstances results in secondary false tracks due to multiple intersections and increased uncertainty during track initiation periods. A combination of field test data playback and Monte Carlo simulations are used to analyze and compare the performance of a distributed UGS cluster to that of an unmanaged centralized cluster.

6242-17, Session 4

Feature selection for real-time tracking

D. F. Hsu, D. M. Lyons, J. Ai, Fordham Univ.

We propose a novel approach, based on Combinatorial Fusion Analysis (CFA) [3], to automatically select sensory features and fusion operations from among the combinatorial options for recognizing and tracking targets that undergo multiple mutual occlusions. The automated tracking of designated targets in a video image is a general problem that has applications in surveillance, multisensor networks, robotics and virtual reality among other areas.

Previous research in recognizing and tracking targets that undergo occlusion has focused on modeling the target in such a way that occlusion can be recognized and corrected [9] or modeling the statistical nature of the occlusion [13]. As a target moves through a series of occlusions in a crowded, urban space, the method for combination and the process of selecting the set of features/evidence that best identifies and tracks the object changes also. Our principal tool in identifying which features or pieces of evidence are most useful is the emerging field of CFA ([3]-[8], [11]-[12], [10], [14], [15], [16]). CFA differs from other approaches to data and information fusion [1] in that it considers: (A) both score and rank function for each feature/evidence and explores the interaction between the two functions, (B) both combinatorial possibility and computational efficiency of combining multiple scoring systems, and (C) multiple scoring systems obtained by a variety of different methods such as probability, statistics, analysis, combinatorics and computation. In our work, we (a) adopt CFA to inspect and analyse the full space of possible combinations of the features or evidence, (b) explore the scoring behavior of each of the features/evidence by computing the rank/score function and propose to use the rank/score function fA to represent the scoring behavior of a feature or piece of evidence A, and (d) use the difference between the two rank/score functions d(fA,fB) to measure the diversity between A and B.

In this paper we present the results of a CFA experiment to select which features and which feature combinations improve tracking performance for several video sequences of multiple targets undergoing a series of mutual occlusions. By "improve," we mean that the feature combination yields a target track that is closer to ground truth than either feature yields on its own. We first demonstrate by comparison with ground truth data that tracking using a combination of an appropriate subset of features will frequently outperform tracking using a combination of all features. We then go on to show that by considering two criteria, a feature performance ratio PR(A,B), and a feature rank/score diversity d(fA,fB), the combinatorial fusion alternative that will improve tracking performance at any point can be predicted.

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6242-18, Session 4

NETWAR

A. A. Keen, 21st Century Technologies

This paper describes technology being developed at 21st Century Technologies to automate Computer Network Operations (CNO). CNO refers to DoD activities related to Attacking and Defending Computer Networks (CNA & CND). Next generation cyber threats are emerging in the form of powerful Internet services and tools that automate intelligence gathering, planning, testing, and surveillance.

We will focus on “Search-Engine Hacks”, queries that can retrieve lists of router/switch/server passwords, control panels, accessible cameras, software keys, VPN connection files, and vulnerable web applications. Examples include “Titan Rain” attacks against DoD facilities and the Santy worm, which identifies vulnerable sites by searching Google for URLs containing application-specific strings. This trend will result in increasingly sophisticated and automated intelligence-driven cyber attacks coordinated across multiple domains that are difficult to defeat or even understand with current technology.

One traditional method of CNO relies on surveillance detection as an attack predictor. Unfortunately, surveillance detection is difficult because attackers can perform search engine-driven surveillance such as with Google Hacks, and avoid touching the target site. Therefore, attack observables represent only about 5% of the attacker’s total attack time, and are inadequate to provide warning.

In order to predict attacks and defend against them, CNO must also employ more sophisticated techniques and work to understand the attacker’s Motives, Means and Opportunities (MMO). CNO must use automated reconnaissance tools, such as Google, to identify information vulnerabilities, and then utilize Internet tools to observe the intelligence gathering, planning, testing, and collaboration activities that represent 95% of the attacker’s effort.

6242-37, Session 4

A fusion approach for coarse-to-fine target recognition

M. Folkesson, C. A. Grönwall, E. Jungert, Swedish Defence Research Agency (Sweden)

A fusion approach in a query based information system is presented. The system is designed for querying multimedia data bases, and here applied to target recognition using heterogeneous data sources. The recognition process is coarse-to-fine, with an initial attribute estimation step and a following matching step. Several sensor types and algorithms are involved in each of these two steps. An independence of the matching results, on the origin of the estimation results, is observed. It allows for distribution of data between algorithms in an intermediate fusion step, without risk of data incest. This increases the overall chance of recognising the target. An implementation of the system is described.

6242-19, Session 5

Minimizing dropped formulas and concepts in knowledge fusion

E. Gregoire, Univ. d’Artois (France)

In this paper, a new approach to fuse inconsistent symbolic logic-based knowledge sources is introduced. Although it is clearly semantic-oriented, it arbitrates conflicting sources using syntax-based concepts. Like many approaches, it implements a preference for minimizing the number of unsatisfied formulas. Its main feature lies in the handling of situations where several solutions exhibiting a same number of falsified formulas are encountered. In these cases, it adopts a preference for the solutions that require dropping formulas involving a minimal number of different terms.

6242-20, Session 5

Distributed sensor data compression algorithm

B. E. Ambrose, F. S. Lin, Broadata Communications, Inc.

Theoretically it is possible for two sensors to reliably send data at rates smaller than the sum of the necessary data rates for sending the data independently, essentially taking advantage of the correlation of sensor readings to reduce the data rate. In 2001, Caltech researchers Michelle Effros and Qian Zhao developed new techniques for data compression code design for correlated sensor data, which were published in a paper at the 2001 Data Compression Conference (DCC 2001). These techniques take advantage of correlations between two or more closely positioned sensors in a distributed sensor network. Given two signals, X and Y, the X signal is sent using standard data compression. The goal is to design a partition tree for the Y signal. The Y signal is sent using a code based on the partition tree. At the receiving end, if ambiguity arises when using the partition tree to decode the Y signal, the X signal is used to resolve the ambiguity. We have extended this work to increase the efficiency of the code search algorithms. Our results have shown that development of a highly integrated sensor network protocol that takes advantage of a correlation in sensor readings can result in 20-30% sensor data transport cost savings. In contrast, the best possible compression using state-of-the-art compression techniques that did not take into account the correlation of the incoming data signals achieved only 9-10% compression at most. This work was sponsored by MDA, but has very widespread applicability to ad hoc sensor networks, hyperspectral imaging sensors and vehicle health monitoring sensors for space applications.

6242-21, Session 5

Fusing diverse monitoring algorithms for robust change detection

K. F. Goebel, W. Yan, N. Eklund, N. Iyer, GE Global Research

Change detection is an important task in remotely monitoring and diagnosing equipment and other processes. Specifically, early detection of differences that indicate abnormal conditions has the promise to provide considerable savings in averting secondary damage and preventing system outage. Of course, accurate early detection has to be balanced against the successful rejection of false positive alarms. In noisy environments, such as aircraft engine monitoring, this proves to be a difficult undertaking for any one algorithm. In this paper, we investigate the performance improvement that can be gained by aggregating the information from a set of diverse change detection algorithms. Specifically, we examine a set of change detectors that utilize techniques from statistic, self-organizing maps, wavelets, among others. The different techniques have different detection sensitivities and different false positive rates. We also examine different fusion schemes. We provide results using illustrative examples from aircraft engine monitoring.

6242-22, Session 5

Noise reduction method for the multisensor system measuring DC current

J. Wang, Y. Geng, Z. Song, J. Wang, Xi'an Jiaotong Univ. (China)

Multi-Sensor system has been proposed to measure electric current in a non-contact way. According to the Ampere's Law, the value of the current flowing in a conductor can be obtained through processing the outputs of the magnetic sensors around the conductor. As the discrete form of the Ampere's Law is applied, measurement noises are introduced when there exists the interference magnetic field induced by nearby current flowing conductors. In this paper, the measurement noises of the multi-sensor system measuring DC current are examined to reveal the impact of the interference magnetic field and the number of the magnetic sensors on the measurement accuracy. A noise reduction method based on Kalman filtering is presented. Computer simulation results show that the method greatly improves the accuracy without seriously increasing the computation load in comparison with other approaches.

6242-23, Session 6

TANDI: threat assessment of network data and information

S. J. Yang, J. Holsopple, Rochester Institute of Technology; M. Sudit, SUNY/Univ. at Buffalo

Cyber attacks typically occur over multiple machines in order to compromise important data or to impair the operation of the network. Parts of these multi-stage attacks are detected by intrusion detection sensors (IDSs). These IDSs generate alerts when suspicious activity occurs on the network. Most of the research in this field aims at correlating these alerts to specific attacks. However, even after the alerts have been correlated, the network administrator or security analyst must manually analyze the attack to determine its current or potential impact. This work presents a graph-based algorithm with nodes using underlying feature trees to automatically analyze the current and potential impact of specific attacks. The novelty of this algorithm lies in the fact that the feature tree allows the separation of how, where, and what the hacker can attack. The correlated IDS alerts and system log entries contain information about how and where the hacker has attacked. These are then combined based on Dempster-Shafer Theorem to determine what has been and what could be attacked (i.e. a database or critical file). The separation of how, where, and what gives the algorithm a manageable number of parameters needed for operation. Implementation of the algorithm allows for real-time notification of potentially insider threat and erroneous results due to mis-detections or an incomplete impact or threat assessment model.

6242-24, Session 6

The challenge of scalable fusion of disparate sources of information

S. J. Julier, ITT Industries - AES Division and Naval Research Lab.; J. K. Uhlmann, Univ. of Missouri/Columbia; J. Walters, ITT Industries - AES Division and Naval Research Lab.

FORCEnet is intended to provide an interconnected set of sensing systems that will be able to collect vast amounts of disparate and complementary information from sensors that are geographically dispersed throughout the battlespace. In principle, this information will lead to better situation awareness so that commanders will be able to act faster and more effectively. However, this capability is possible only if the raw sensor data can be fused and synthesized for distribution to the right user in the right form at the right time.

In this paper we consider the problem of developing Level 1 data fusion algorithms for disparate fusion in Net-Centric Warfare. These algorithms must be capable of operating in a fully distributed (or decentralized) manner; must be able to scale to extremely large numbers of entities; and must be able to combine many disparate types of data. We argue that the problems are a direct extension of those encountered in more traditional data fusion systems.

To meet these needs we propose a framework that consists of three main components: a canonical state representation which treats an entity's state as a collection of attributes; fusion algorithms to combine these states together in a manner that is consistent and robust even in ad hoc networks; and simplification methods to remove attributes and compress uncertainty distributions to satisfy security, bandwidth, and computational constraints.

6242-25, Session 6

Fuselets: an agent-based architecture for fusion of heterogeneous information and data

J. Beyerer, M. Heizmann, Fraunhofer-Institut für Informations- und Datenverarbeitung (Germany); J. Sander, Univ. Karlsruhe (Germany)

A new architecture for fusing information and data from heterogeneous sources is proposed. The approach takes criminalistics as a model. In analogy to the work of detectives, who attempt to investigate crimes, software agents are initiated that pursue clues and try to consolidate or to dismiss hypotheses. Like their human pendants, they can, if questions beyond their competences arise, consult expert agents. Within the context of a certain task, region, and time interval, specialized operations are applied to each relevant information source, e.g. IMINT, SIGINT, ACINT, ..., HUMINT, data bases etc. in order to establish hit lists of first clues. Each clue is described by its pertaining facts, uncertainties, and dependencies in form of a local degree-of-belief (DoB) distribution in a Bayesian sense. For each clue an agent is initiated which cooperates with other agents and experts. Expert agents support to make use of different information sources. Consultations of experts, capable to access certain information sources, result in changes of the DoB of the pertaining clue. According to the significance of concentration of their DoB distribution clues are abandoned or pursued further to formulate task specific hypotheses. Communications between the agents serve to find out whether different clues belong to the same cause and thus can be put together. At the end of the investigation process, the different hypotheses are evaluated by a jury and a final report is created that constitutes the fusion result.

The approach proposed avoids calculating global DoB distributions by adopting a local Bayesian approximation and thus reduces the complexity of the exact problem essentially.

Different information sources are transformed into DoB distributions using the maximum entropy paradigm and considering known facts as constraints. Nominal, ordinal and cardinal quantities can be treated within this framework equally. The architecture is scalable by tailoring the number of agents according to the available computer resources, to the priority of tasks, and to the maximum duration of the fusion process. Furthermore, the architecture allows cooperative work of human and automated agents and experts, as long as not all subtasks can be accomplished automatically.

6242-26, Session 6

Data fusion on a distributed heterogeneous sensor network

P. Lamborn, Mississippi State Univ.; P. Williams, Sandia National Labs.

Alarm-based sensor systems are being explored as a tool to expand perimeter security for facilities and force protection. However, the collection of increased sensor data has resulted in an insufficient solution that includes faulty data points. Data analysis is needed to reduce nuisance and false alarms, which will improve officials' decision making and confidence levels in the system's alarms. Moreover, operational costs can be

allayed and losses mitigated if authorities are alerted only when a real threat is detected. In the current system, heuristics such as persistence of alarm and type of sensor that detected an event are used to guide officials' responses. We hypothesis that fusing data from heterogeneous sensors in the sensor field can provide more complete situational awareness than looking at individual sensor data. We use a two stage approach to reduce false alarms. First, we use self organizing maps to cluster sensors based on global positioning coordinates and then train classifiers on the data collected within each cluster to obtain a local view of the detected event. Then, we train a classifier on the local results to compute a global solution. We investigate the use of machine learning techniques, such as k-nearest neighbor, neural networks, and support vector machines to improve alarm accuracy when compared with a weighted voting algorithm. On simulated sensor data, the proposed approach identifies false alarms with greater accuracy than a weighted voting algorithm.

6242-27, Session 6

Processing heterogeneous XML data from multisource

T. Wang, Harbin Engineering Univ. (China); X. Lin, Harbin Institute of Technology (China)

XML has become the de facto standard for data interchange over the Internet and many hot applications such as network monitoring, XML packet routing, etc over the Internet require to evaluate large scale of queries on XML streams, most of which always come from different sources with different DTDs. Recently XML heterogeneity has become a new challenge. In this paper, we propose a novel clustering strategy to regrouping these heterogeneous XML documents, for searching in a relative smaller space with certain similarity can reduce cost. We extract features about paths and then map them into High-dimension Vector Space (HDVS), which is indexed by string R-tree. By the novel similarity metric we proposed, heterogeneous documents are indirectly clustered on HDVS. However, in traditional method, document is always mapped into VSM and cluster directly. Fuzzy c-means clustering is used in the strategy and experiments show the proposed method outperformed the traditional methods.

6242-28, Session 7

A preprocessing and automated algorithm selection system for image registration

A. L. Drozd, A. C. Blackburn, ANDRO Computational Solutions; P. K. Varshney, Syracuse Univ.; I. P. Kasperovich, ANDRO Computational Solutions; M. Xu, B. Kumar, Syracuse Univ.

This paper will describe development of a system that provides image preprocessing and automatically selects an image registration algorithm based on what is known about or measured from a pair of images.

Prior to registration, certain preprocessing needs to be performed to improve the results of the process. Some of the preprocessing includes image noise detection and reduction, resampling to address differences in scale between images, and chipping out overlapping portions of images.

Also applied are techniques for characterizing image content, such as Fisher information, Gabor features, and entropy analysis. The results of these analyses are then used to select the best registration algorithm for an image pair.

The system described is part of a larger data registration toolkit, known as SMART, which provides additional capabilities, such as registration quality metrics and registration of non-image data.

6242-29, Session 7

A measure for performance comparison of image registration methods

B. Kumar, P. K. Varshney, Syracuse Univ.; A. L. Drozd, ANDRO Computational Solutions

Intensity based image registration is one of the most popularly used methods for automatic image registration. In the recent past, various improvements have been suggested, ranging from variation in the similarity metrics (Correlation Ratio, Mutual Information, etc.) to improvement in the interpolation techniques. The performance of one method over the other is observed either from the tally of final results of registration or visual presence of artifacts in the plots of the objective function (similarity metric) vs. the transformation parameters. None of these are standard representations of the quality of improvement. The final results are not indicative of the effect of the suggested improvement as it depends on various other components of the registration process. Also visual assessment of the presence of artifacts is feasible to visualize only when the number of parameters in the transformation involved are less than or equal to two.

The intensity based registration methods can be modeled as an optimization problem. The similarity metric used, for example Mutual Information, becomes the objective or fitness function of the optimization problem. In this paper, we introduce quality of objective-function landscape and the difficulty in searching the optimum, as a metric for comparing different variants of intensity based methods of registration. In this metric we are exploiting the correlation between the distance of any point in the search space from the optimum and, value of the objective function at that point. Unlike the already existing methods of comparison this metric provides a quantitative measure that can be used to rank different algorithms. In this paper, we compare and rank different interpolation techniques. Our experimental results show that the relative ordering provided by the metric is consistent with the observation made by traditional approaches like visual interpretation of the similarity metric plot. We also compare and compute the metric for different variants of intensity based methods.

6242-30, Session 7

MeRis and ETM image fusion for spatial resolution improvement

S. Mathieu, Alcatel Alenia Space (France); A. Minghelli-Roman, Univ. de Bourgogne (France); L. Polidori, Institute of Research for Développement (France); L. Loubersac, Institut Français de Recherche pour L'Exploitation de la Mer (France); F. Cauneau, École des Mines de Paris (France)

MeRIS was launched in March 2002 and has been providing images since June 2002. Before its launch, we had implemented a method to improve its resolution by merging its images with Landsat ETM images in order to preserve the best characteristics of the two images (spatial, spectral, temporal). We now present the results of this method for real MeRIS images (level 1b and 2) in a coastal area. The robustness of the method is studied as well as the influence of the delay between the acquisitions of the two images

6242-32, Session 7

A novel ICA domain multimodal image fusion algorithm

N. S. Cvejic, N. Canagarajah, D. R. Bull, Univ. of Bristol (United Kingdom)

We present a novel ICA domain multimodal image fusion algorithm. It uses weighting of the ICA bases and Petrovic fusion performance metric in order to maximize the subjective quality of the fused image. Experimental results confirm that the proposed method outperforms the basic ICA method, as for both Petrovic and Piella metric the proposed method obtains higher metric values than the basic ICA and TopoICA algorithm.

6242-33, Session 7

A novel image fusion algorithm based on human vision system

Q. Miao, B. Wang, Xidian Univ. (China)

The Human Vision System (HVS) is an import fundament for digital image processing. We can process the digital images with methods that are similar with the processing procedure of HVS for human. If so, we can get a good result that is consistence with human's visual effect. So far, lots of scholars have gotten many achievements in digital image processing with the help of the properties of HVS.

The pulse coupled neural network (PCNN) has a significant biological background and was introduced by Eckhorn as a research effort to explain the synchronous pulse bursts in the visual cortex of the cat and monkey. The physiologically motivated PCNN has an extraordinary advantage in image processing over other methods scientists have ever used. It can be applied to a large variety of research fields as diverse as image smoothing, image segmentation, image feature extraction, image shadow removal, image object detection, and so on. But PCNN is not convenient in application in that the number of parameters which need to be adjusted is large and they affect each other greatly.

The proposed new fusion algorithm is based on the improved pulse coupled neural network model, the fundamental characteristics of images and the properties of human vision system. In almost all the literatures about image processing with PCNN, the linking strength Beta of each neuron are often assigned with the same value. It is chosen with experiments or experiences. It is obvious not a good way to do the process with experience. This shortcoming is a big limit to the automatic process and the generalization for PCNN. For the visual system of eyes, it is impossible that all the linking strengths of neurons are the same value. The linking strength of a real neuron should be related to the thickness of the blood sugar, the electrolyte, the age, the temperature and the situation of the neuron cell. In fact, almost all the problems above are not considered in the simplified neuron model of PCNN. Compared with the traditional algorithm where the linking strength of each neuron is the same and its value is chosen with human involvement, this algorithm uses the contrast of each pixel as its value, so that the linking strength of each pixel can be chosen adaptively. It greatly reduces human involvement and therefore improves the automation of PCNN image processing. Furthermore, by this algorithm, other parameters, for example, Delta, the threshold adjusting constant, only have a slight effect on the new fused image. It therefore overcomes the difficulty in adjusting parameters in PCNN. Experiments show that the proposed algorithm works better in preserving the edge and texture information than the wavelet transform method and the Laplacian pyramid method do image fusion.

6242-34, Session 7

The finite ridgelet transform for image fusion

Q. Miao, B. Wang, Xidian Univ. (China)

In many image fusion applications, such as remote sensing and mapping images, multi-focus images, multi-modality medical images, the fusion strategy is a very important issue. In recent years, many image fusion techniques and software tools have been developed. The well-known methods are, for example, the weighted average method, HIS(Intensity, Hue, Saturation) color model, the PCA(Principal Components Analysis) method, the Laplacian method, and wavelet based method.

For fusing satellite images, wavelet-based fusion method provides high spectral quality. However, the fused image by wavelet method has much less spatial information than those by some other methods. In the same way, for fusing multi-focus images or other images, the edge-effect is an important problem for wavelet method and could not be ignored. In other words, it is necessary to develop advanced image fusion method so that the fused images have the ideal result with minimum artifacts.

Many image processing tasks take advantage of sparse representations of image data where most information is packed into a small number of samples. Typically, these representations are achieved via invertible and non-redundant transforms. Currently, the most popular choices for this purpose is the wavelet transform. The success of wavelets is mainly due to the good performance for piecewise smooth functions in one dimension. Unfortunately, such is not the case in two dimensions. In essence, wavelets are good at catching zero-dimensional or point singularities, but two-dimensional piecewise smooth signals resembling images have one-dimensional singularities. That is, smooth regions are separated by edges, and while edges are discontinuous across, they are typically smooth curves. Intuitively, wavelets in two dimensions are obtained by a tensor-product of one dimensional wavelets and they are thus good at isolating the discontinuity across an edge, but will not see the smoothness along the edge.

To overcome the weakness of wavelets in higher dimensions, Candμes and Donoho recently pioneered a new system of representations named ridgelets which deal effectively with line singularities in 2-D. The idea is to map a line singularity into a point singularity using the Radon transform. Then, the wavelet transform can be used to effectively handle the point singularity in the Radon domain. Their initial proposal was intended for functions defined in the continuous R2 space.

Image is a finite 2-D signal. So it should be considered as one period of a periodic signal. In this way, we can use finite ridgelet transform to complete the image processing problems. In recent journals, we can find that finite ridgelet transform is used in image denoising, image compression and so on. As an illustration, consider the image denoising problem where there exist other approaches that explore the geometrical regularity of edges, for example by chaining adjacent wavelet coefficients and then thresholding them over those contours. However, the discrete ridgelet transform approach, with its "built-in" linear geometrical structure, provide a more direct way by simply thresholding significant ridgelet coefficients in denoising images with straight edges.

Currently, the most popular transform used in image fusion of multi-scale analysis are the Laplacian transform and wavelet transform. Finite ridgelet transform adopts the radon transform to map the line singularity to point singularity. And then, it uses 1-D wavelet transform to implement the mapping from the slice of radon domain to wavelet domain. So we can get the singularity easily with methods that are usually adopted by wavelet method. Through processing the coefficients of the finite ridgelet transform, we can get the fused image with clear edges, good visual effect.

In this paper, we introduce a new image fusion method based on the finite ridgelet transform. The fused image using ridgelet-based image fusion method represents almost the same detail as the original image because ridgelets represent edges better than wavelets, and the same color as the original multi-spectral images because we use the wavelet-based image fusion method naturally in our algorithm. Therefore, this new method is an optimum method for image fusion based on the finite ridgelet transform.

Experiments show that the proposed algorithm works better in preserving the edge and texture information than the wavelet transform method some other methods do in image fusion. The visual analysis and quantitative analysis are consistent in the fusion experiments.

6242-35, Session 7

The contourlet transform for image fusion

Q. Miao, B. Wang, Xidian Univ. (China)

For one-dimensional piecewise smooth signals, like scanlines of an image, wavelets have been established as the right tool, because they provide an optimal representation for these signals in a certain sense. In addition, the wavelet representation is amenable to efficient algorithms; in particular it leads to fast transforms and convenient tree data structures. These are the key reasons for the success of wavelets in many signal processing and communication applications; for example, the wavelet transform was adopted as the transform for the new image-compression standard, JPEG-2000. In capturing the geometry of image edges, however, there are limitations of the commonly used separable extensions of wavelet transforms. Natural images are not simply stacks of 1-Dpiecewise smooth scan-lines; discontinuity points(i.e. edges) are typically located along smooth curves(i.e. contours) owing to smooth bound-

aries of physical objects. Thus natural images contain intrinsic geometrical structures that are key feature in visual information. As a result of a separable extension from 1-D bases, wavelets in 2-D are good at isolating the discontinuities at edge points, but will not “see” the smoothness along the contours. In addition, separable wavelets can capture only limited directional information-an important and unique feature of multidimensional signals.

Fortunately, Minh N. Do and Martin Vetterli recently pioneered a new system of representations named contourlets which is a “true” two dimensional transform that can capture the intrinsic geometrical structure that is key in visual information. The idea is to construct a discrete-domain multi-resolution and multi-direction expansion using non-separable filter banks, in much the same way that wavelets were derived from filter banks. This construction results in a flexible multi-resolution, local, and directional image expansion using contour segments, and thus it is named the contourlet transform. The discrete contourlet transform has a fast iterated filter bank algorithm that requires an order N operations for N-pixel images. With parabolic scaling and sufficient directional vanishing moments, contourlets could achieve the optimal approximation rate for piecewise smooth functions with discontinuities along twice continuously differentiable curves.

In many image fusion applications, such as remote sensing and mapping, multi-focus images, multi-modality medical images, the fusion strategy is a very important issue. In recent years, many image fusion techniques and software tools have been developed. The well-known methods are, for example, the weighted average method, HIS(Intensity, Hue, Saturation) color model, the PCA(Principal Components Analysis) method, and wavelet based method.

The contourlet transform is a new two-dimensional extension of the wavelet transform using multiscale and directional filter banks. The contourlet expansion is composed of basis images oriented at various directions in multiple scales, with flexible aspect ratios. Given this rich set of basis images, the contourlet transform effectively captures smooth contours that are the dominant feature in natural images.

Currently, the most popular transform to used in image fusion of multiscale analysis are the Laplacian transform and wavelet transform. Contourlet transform adopts the Laplacian pyramid to obtain a multiscale decomposition. And then, it uses iterated Directional Filter Banks(DFB) to implement the multi-directional decomposition. Since the directional filter bank could be used to capture the high frequency (representing directionality) of the input image, the low frequency content is poorly handled. In fact, the low frequency would “leak” into several directional subbands, hence the DFB alone does not provide a sparse representation for images. This fact provides another reason to combine the DFB with a multiscale decomposition, where low frequencies of the input image are removed before applying the DFB. Then we can process the contourlet transform coefficients of the images.

In this paper, we introduce a new image fusion method based on the contourlet transform. Contourlet transform is more appropriate for the analysis of the signals which have line or hyperplane singularity than wavelet, and it has better approximation precision and sparsity description. When introducing contourlet transform to image fusion, we can take the characteristics of original images well and provide more information for fusion. The ability of noise restraint is also better than wavelet transform. The fused image using contourlet-based image fusion method represents almost the same detail as the original image because contourlets represent edges better than wavelets. Therefore, this new method is an optimum method for image fusion. Finally, we show some numerical experiments demonstrating the image fusion applications of contourlets transform.

Conference 6243: Enabling Photonics Technologies for Defense, Security, and Aerospace Applications II

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6243-01, Session 1

AFRL highly integrated photonics (HIP) program

M. A. Horne, H. Schantz, G. J. Whaley, S. Newcomer, Lockheed Martin Corp.

This presentation will describe the Air Force Highly Integrated Photonics Program (AF HIP) and its objective to integrate on a monolithic device, all of the optical components required to serve as a node in an all optical communication network. This research and development program utilizing advanced technologies in silicon on insulator (SOI) and developing technologies using standard silica to design, develop, characterize, and demonstrate highly integrated photonic devices that can be transitioned into both current and emerging tactical platforms for the U.S. Air Force. This effort is developing key technologies to overcome several of the existing constraints with respect to the integration and packaging aspects of the current generation of COTS optical devices. Monolithic integration (chips fabricated out of a single material system) remains the ultimate vision for integrated optics.

6243-02, Session 1

SOI photonics technology for defense, and security

J. K. Chan, R. Dutt, APIC Corp.

APIC (Advanced Photonics Integrated Circuits) Corporation is engaged in HIP (Highly Integrated Photonics) and HIPE (Highly Integrated Photonics and Electronics) chip technology for Defense and Homeland Security applications. This technology allows reduced chip size, eliminates numerous pigtails/interconnects thus improving system reliability and reducing cost. Mid Pacific Photonics Prototyping Facility (M3PF) is a Navy funded 8" SOI photonics prototyping facility constructed to meet this need. Among other high-tech equipment, M3PF is equipped with a high resolution ASML QML stepper, a lithography tool capable of 0.25 um resolution, and a field size of 32.5 mm by 22 mm. APIC is developing processing techniques for both fiber-compatible core size waveguides as well as CMOS compatible core size waveguides. In this paper, SOI photonics technology and M3PF will be described. Processed chips, their performance and applications will be presented to demonstrate the efficacy of M3PF. Additional processing capabilities such as wafer bonding for heterogeneous integration processing, which plays a key role in HIPE chip implementation, will be presented.

6243-03, Session 1

Highly integrated DWDM photonics modules for avionics networks

A. J. Bruce, J. Shmulovich, S. V. Frolov, Inplane Photonics, Inc.; G. J. Whaley, H. Schantz, M. A. Horne, Lockheed Martin Corp.

We will describe the configuration and performance of a new Highly Integrated Photonics module based on a Lossless Bus Interface Chip (LBIC) manufactured using Planar Lightwave Circuit (PLC) technology. This component is targeted for a range of applications in Avionics and similar LANs where size, weight and reliability are critical.

Functionally, the LBIC module provides for a channel selectable drop facility with through channel transparency across the communications C-band.

6243-04, Session 1

Fabrication and testing of laser communication terminals for aircraft

M. E. Gangl, ITT Industries, Inc.

Abstract not available.

6243-05, Session 2

All-optical networks for platforms connected to the global information grid

P. S. Guilfoyle, OptiComp Corp.; W. D. Hodges, The Boeing Co.

The advent of network centric operations and the Global Information Grid have highlighted the need for ultra-wide bandwidth networks to efficiently and securely route multi-gigabit data streams among air, space, and ground platforms. Boeing, with expertise in platform integration and network centric operations, in conjunction with OptiComp Corporation's (OCC) advanced photonic technology, is developing an all optical network using wave division multiplexing (WDM) and vertical-cavity surface emitting lasers (VCSEL). Current VCSEL-based solutions have not integrated WDM or other functionality enhancements for improved network performance. OCC is developing a novel approach that implements advanced switching architectures by distributing integrated, WDM, VCSEL-based modules at each node in the network. This network design enables high data throughput and switching speeds, low latency, and system scalability through advanced system topologies and monolithically integrated optoelectronics. The distributed WDM switch consists of pairs of monolithically integrated VCSELs and resonant cavity photodetectors, each at a different wavelength, interconnected along a common waveguide with all multiplexing and demultiplexing done on-chip. Different levels of connectivity and functionality are available by interconnecting the optoelectronic switches in various configurations. A distributed crossbar switch with N access ports, referred to as an N3 architecture (N3 interconnect paths), can be realized by interconnecting an N-element VCSEL array with an array of N photodetectors. Each VCSEL and photodetector are connected using an interconnect media such as silica-based waveguides and/or optical fibers. Using this configuration, each port can listen to all interconnect paths simultaneously. When a port senses no traffic on an interconnect path, it can transmit its signal onto that path. This implementation can use single-wavelength switches on parallel interconnect paths, or alternatively an N3 network can be realized with WDM optical switches operating along a single interconnect path. Further complexity in network topology allows for the realization of N4 architectures by using parallel, WDM, N3 systems. N4 topologies allow for increased scalability, thus dramatically increasing the data handling capacity of the network, as well as the number of nodes that can be accommodated.

6243-06, Session 2

Proposal for free-space optical communication network using WDM homodyne PSK facilitated by cloning of carrier-envelope phase-locked oscillators

C. R. Doerr, P. J. Winzer, Lucent Technologies/Bell Labs.

High-bandwidth satellite (or other free-space) communications beneficially use optical inter-satellite links (ISLs) rather than conventional radio-

frequency technology because of the reduced diffraction at optical wavelengths. It is known that homodyne phase-shift keying (PSK) theoretically gives 6-dB sensitivity gain over intensity modulation and optically preamplified direct detection. The highest sensitivity ever reported for an optical link was homodyne PSK at 565 Mb/s[ ]. High sensitivity translates directly into size, weight, and power (SWAP) savings. Also, it is known that wavelength-division multiplexing (WDM) is a practical way to transmit a very high bandwidth (> 1 Tb/s) across a link.

Our proposal is to use novel carrier-envelope phase-locked (CEPL) oscillator cloning to enable low-SWAP homodyne WDM-PSK. The network will consist of satellites separated into domains, each domain with a master satellite. Each master will carry an atomic-referenced CEPL oscillator. A micro mode-locked laser (* MLL) aboard each satellite will be phase and frequency locked to the CEPL master. Lines from the * MLL comb will be independently phase encoded with data streams and transmitted to other satellites. A * MLL in the receiving satellite will serve as the local oscillator (LO) for homodyne detection. The CEPL nature guarantees that the LO comb has low noise and the pull-in range will be small, speeding link set-up time and further reducing SWAP.

B. Wandernoth, “20 photon/bit 565Mbit/s PSK homodyne receiver using synchronisation bits,” Electron. Lett., vol. 28, pp. 387-388, 1992.

6243-07, Session 2

TCP-Fiber: direct measurement optical transport congestion control for beyond 10-gigabit networks

M. I. Kazantzidis, Broadata Communications, Inc.

Optical communication systems could currently allow petabytes of data to be transferred to geographically distributed tera-scale computing facilities at beyond 10Gbps rates. While the bandwidth is available in network link technology, transport protocols like TCP/IP and common network protocol architectures severely limit the attainable throughput over such links. Traditional layering -that is implemented through excessive per-byte (word) memory bandwidth constrained buffer copying, transport processing complexity, combined error and congestion control and trial and error timeout-based approaches results in prohibitively increasing performance degradation as network speeds increase. In this paper we present TCP-Fiber, a TCP version that is based on direct measurements of available and bottleneck link bandwidth and is able to perform decoupled error and congestion control while supporting zero-copy from application to network interface. A key innovation in TCP-Fiber is a variable length “packet train” based method that allows sensing optical ultra high bandwidths with the use of common timers. A TCP-Fiber connection is able to fairly send at the full network rate without extensive trial-and-error convergence procedures or waiting on time-out for unacknowledged packets, while maintaining network stability.

6243-08, Session 2

Wavelength division multiplexing and transmission of analog signals over fiber

W. D. Potter, Univ. of Connecticut

We present results from the multiplexing and transmission of amplitude modulated, frequency modulated, and video analog signals over fiber. The optical carrier’s wavelengths for these signals were centered in the 1545 - 1560 nm telecommunication wavelength regimes. A direct modulation format was used for the AM signals whereas external modulation formats were used for the FM and video signals. Standard telecommunication WDM components were used for multiplexing and demultiplexing of the signals. The study presents a comparison of the original electrical signal and the transmitted signals. In particular we indicated intermodulation effects, and signal-to-noise ratio as a function of wavelength separation of the optical carriers and transmission distance respectively. The practical application of this research will help stimulate the growing trend to add fiber optic cable to the “Last Mile”. The Last Mile, a reference to the connection between the residential customer and the Central Office is currently dominated by three independent technologies Copper Wire, Wireless and Coaxial cable. These methods of transmitting Analog signals dictate the speed and the amount of information that can be delivered to the residential customer. The preferred transmission media used to connect computers, the primary source of digital signals, either locally or over long distances is through Fiber Optic Cable. If Fiber Optic Cable could replace the existing last mile, this would elevate the present bandwidth issues. The addition of yet another cable into the home for a single application is prohibitively expensive. Therefore the need to combine all existing signals both digital and analog into any additional transmission media on the Last Mile is essential.

6243-09, Session 2

The Optical Harness(tm): a light-weight EMI-immune replacement for legacy electrical wiring harnesses

J. B. Stark, S. Jackson, W. Trethewey, Defense Photonics Group

Electrical wiring harnesses have been used to interconnect control and communication equipment in mobile platforms for over a century. Although they have served this function successfully, they have three problems that are inherent in their design: they are heavy, they are stiff, and they are prone to Electro-Magnetic Interference (EMI) when not properly shielded. These properties are all aspects of the metallic conductors used to build the harnesses.

The Optical Harness (TM) is a photonic replacement for the legacy electrical wiring harness. The Optical Harness (TM) replaces the signal wires in an electrical harness with light-weight optical fiber. The original electrical connector presentations of the legacy wiring harness remain, making the Optical Harness (TM) a direct replacement. A Line Replaceable Unit (LRU) attached to the Optical Harness (TM) does not distinguish between the legacy electrical wiring harness and its photonic replacement. There is no need to redesign the LRUs to replace the electrical harness with one that is light weight, thin and flexible, and immune to EMI.

Electrical connection to the LRUs is made using the same connector headshell. In the backshell of the connector, the electrical signals are converted to optics, and transported on optical fiber. Each connector on the Optical Harness (TM) has the circuitry required to convert the signals, to transport the optical signals to their destinations, and to convert them back to electrical signals for the LRUs. This makes the Optical Harness (TM) an optical network, which is managed by controllers inside the connector backshells. The network is deterministic, redundant and fault-tolerant.

6243-10, Session 3

Advances in coherent optical communications

G. Li, C. Kim, Y. Han, College of Optics and Photonics/Univ. of Central Florida

This paper describes recent advances in coherent techniques for digital and analog optical transmission. Coherent reception, in particular, in combination with digital signal processing can improve dispersion tolerance and spectral efficiency for digital transmission and linearity for analog transmission.

6243-11, Session 3

Coherent homodyne receiver systems based on a mode-locked semiconductor laser for an optical coherent CDMA system

W. Lee, H. Izadpanah, M. Choi, P. J. Delfyett, Jr., College of Optics and Photonics/Univ. of Central Florida; S. Etemad, Telcordia Technologies, Inc.

High detection sensitivity and large multi-user interference rejection are

key requirements to accommodate higher number of users in an optical coherent CDMA system. In this work, we propose efficient coherent homodyne receiver systems configurations, as well as, demonstrate experimentally the performance of coherent homodyne pulse detection using a synchronized modelocked semiconductor laser system. We present the significant improvement of coherent gain and signal-to-noise ratio of the NRZ format modulated PRBS data detection compared with direct detection.

6243-12, Session 3

Duobinary transmission using coherent detection

G. Goldfarb, C. Kim, G. Li, College of Optics and Photonics/ Univ. of Central Florida

The impact of chromatic dispersion on the complex electric field of an optical phase-coded duobinary signal is investigated through numerical simulation. Dispersion causes distortion and rotation of the optical constellation with increasing transmission distance, leading to eye closure of the received signal. When direct detection is employed rapid eye closure starts after approximately 213km. Employing coherent detection increases this dispersion limit by 70km.

6243-13, Session 3

Complex constellation diagram measurement for optical communication

I. Kim, G. Li, College of Optics and Photonics/Univ. of Central Florida

Complex envelope measurement using coherent linear optical sampling is investigated. It is shown that reliable measurement of the phase requires that one of the optical modes of the mode-locked laser be locked to the optical carrier of the data signal to be measured. Measurement errors of the intensity profile and phase depend on the pulsewidth and chirp of the sampling pulses as well as the detuning between the carrier frequencies of the data signal and the center frequency of sampling source. This technique has been applied to measurement of DPSK signal.

6243-14, Session 4

Coherent optical receiver system with balanced photodetection

R. Howard, A. M. Joshi, D. Mohr, D. Becker, C. Wree, Discovery Semiconductors, Inc.

We report the development of a heterodyne fiber optic coherent balanced receiver with a small laboratory footprint. The receiver incorporates a DFB laser local oscillator, fiber optic combiner/splitter, adjustable fiber optic delay line, balanced dual pin photo detector, RF post amplifier, optical phase lock loop, and precision power supplies, in a small instrument case. Test data presented will show shot noise limited detection of amplitude and phase modulated signals, cancellation of laser RIN noise, and line width narrowing of the local oscillator laser. Several examples of coherent balanced detection as enabling technology for high value applications in secure digital communication, high dynamic range analog links, and remote sensing will be presented.

6243-15, Session 4

All-optical switching and wavelength conversion using passive nonlinearities in semiconductor quantum wells

J. Nah, P. LiKamWa, College of Optics and Photonics/Univ. of Central Florida

A silica capped impurity-free vacancy induced disordering is used in the fabrication of an all-optical integrated Mach-Zehnder switch incorporating a linear waveguide directional coupler with nonlinear multiple quantum well (MQW) sections. The MQW structure consists of seven compressively strained InGaAs quantum wells, each 7nm thick separated by eight lattice matched InGaAsP barriers, each 14nm thick. Selective area intermixing of the MQWs was achieved by capping only the regions to be disordered with a 200nm thick film of silica. The device contains two nonlinear arms that are each 750μm long connected to a 3-dB directional coupler made of two waveguides separated by a gap of 1μm.

In order to setup the device for all-optical wavelength conversion, the beam from a cw laser diode operating at a wavelength of 1550nm, is split into two and launched into the device. The phase delay is carefully adjusted so that all the optical energy exits the device through the lower output port. Switching into the upper output port is achieved using a harmonically modelocked erbium doped fiber laser that produces 50ps pulses at a repetition frequency of 1GHz. The modelocked pulses are split into two beams and launched into the two nonlinear sections of the device with a time delay of 135ps between them. Owing to the differential nonlinear phase change, the 1550nm light is switched into the upper port effectively regenerating and changing the wavelength of the modelocked pulses into 1550nm pulses. The device should be able to perform switching and wavelength conversion on 1ps time scale.

6243-16, Session 4

Low-voltage electro-optic polymer modulators

R. Dinu, D. Jin, A. M. Barklund, D. Huang, L. Zheng, M. K. Koenig, S. G. Ferrier, Y. Fang, Lumera Corp.

Electro-optic (EO) polymer modulators have been used to demonstrate high speed external modulation of optical signals. EO polymers have closely matched refractive indices at optical and microwave wavelengths, which also enables high bandwidth operation. An EO polymer includes an organic “push-pull” chromophore that can be modified to give poled polymers with high EO activity. This high EO activity and optical-microwave velocity match together offer the promise of accomplishing broadband, high speed optical modulation with low drive voltage. Such optical signal modulation is critical for applications in phased array radar and RF photonics. However, practical fabrication of optical modulators that realize the potential of EO polymers requires clad materials with optimized properties such as conductivity, dielectric constant, optical loss, and refractive index. In addition, other practical issues such as electrode design, optical fiber coupling, and hermetic packaging are critical in final device performance.

We report on high-speed electrode parameters as well as electro-optic performance versus frequency for modulators fabricated on 6" silicon wafers. Special attention was paid to designing claddings to match the electro-optic core conductivity and dielectric constant. The r33 values measured on single layer thin films are compared with those resulting from V(pi) measurements on devices. We compare results obtained from devices fabricated using commercially available UV-curable epoxies with devices fabricating using proprietary clad polymers developed at Lumera Corporation. RF data up to 40GHz on packaged devices, and extinction ratio data at voltages ranging from V(pi) to as low as 0.25V is presented, proving once more that polymer modulators may be useful in applications requiring low power consumption and large bandwidths.

6243-17, Session 4

Tunable multimode interference devices

D. A. May-Arrioja, P. LiKamWa, College of Optics and Photonics/Univ. of Central Florida

The ability to fine-tune the splitting ratio of 1x2 couplers represents a great advantage in many applications. In this paper, we report on the studies of the tuning characteristics of multimode interference (MMI) splitters. It is found that for good control of the power balance, the refractive index change needs to be controlled in a very small localized area only. In

many cases, the required index change has to be obtained through carrier injection. Therefore, the issue of current spreading is critical to the device performance. We have experimentally characterized a zinc in-diffusion technique that allows for the selective definition of p-i-n regions. The zinc in-diffusion process was performed using a semi-sealed open-tube diffusion furnace. The method is simple, yet highly controllable and reproducible, with the crystal quality remaining intact after the diffusion. By using this technique, current spreading can be effectively regulated, and zinc in-diffusion is therefore ideal for fabricating tunable MMI couplers. The only drawback when using this approach is that an effective index change is induced within the contact area. This can lead to undesired phase modifications within the MMI that can adversely affect the imaging of the device. We have simulated such an effect on the performance of MMI couplers, and we demonstrate that, with proper selection of the index modulated regions, the selected splitting ratio is negligibly affected. Ideally, the splitting ratio can be continuously tuned across a range of 0-100%, making the devices attractive as photonic switches too. Devices are currently being fabricated and experimental results will be presented.

6243-18, Session 4

Computing fields in a cyclindrically curved dielectric layered media

A. D. McAulay, Lehigh Univ.

In a previous paper (SPIE 6014-17, Oct., 2005) we showed how the matrix method may be used to compute leaky wave interconnections for a dielectric waveguide in the absence of bends. In this paper we extend the method to analyze a polymer planar layered dielectric media that is bent around a cylinder, causing leaky waves to propagate out uniformly from the layered waveguide. The intensity of the leaking light is determined by first converting the cylindrical configuration into a Cartesian coordinate system. In the process the dielectric media is altered to provide an equivalent plane layer model. This model is solved using the matrix method to determine how the strength of the radiation depends on the curvature of the waveguide stack. This problem can arise when determining losses due to the bend in integrated optic circuits mounted on cylindrical forms. A segment of the curved layered media can be used as a mechanical light switch for which light is switched off when the media is flat and radiates when the media is curved. Other applications are discussed.

6243-20, Session 5

Injection characterization of packaged bi-directional diamond-shaped ring lasers

R. J. Bussjager, S. T. Johns, M. J. Hayduk, J. M. Osman, V. Kovanis, Air Force Research Lab.; A. J. Morrow, M. Green, BinOptics Corp.; N. Stoffel, S. Tan, C. Shick, Infotonics Technology Ctr.; W. H. Bacon, B. Beaman, Eastman Kodak Co.

The Air Force Research Laboratory, BinOptics Corp., and Infotonics Technology Center worked collaboratively to package and characterize diamond shaped ring lasers operating in the 1550 nm range. The lasers propagate bi-directionally but can be forced into unidirectional propagation via laser injection, or by implementing an integrated external mirror. Round trip length is 500 μm through 3.5 μm wide ridge waveguides. Four anti-reflection coated, polarization maintaining, lensed fibers provide input/output addressing. The lasers are polarized horizontal to the substrate. Laser threshold current is ~ 40 mA and has a saturation current of 160 mA providing an average maximum output power of ~ 1 mW out of one of the arms. Focus with this project was on optimizing laser injection performance. Various parameters were investigated to provide switching. These include minimal and maximum optical power injection thresholds and biasing requirements. Relaxation oscillations do not seem to be a problem and gain quenching does not seem to occur as a function of bias current or injected power levels. Results are shown from cascading multiple devices together and are affiliated with some potential applications. Some theoretical analysis in ring laser behavior is provided. Also mentioned in this paper are some packaging characteristics. The prototype package design was constrained to modification of a prior optoelectronic package in order to reduce cost and wait time. These lasers seem to be promising in that they switch cleanly when biased properly and injected with properly polarized light at the right power level.

6243-21, Session 5

Mode-locked fiber lasers

N. K. Dutta, Univ. of Connecticut

Mode locked fiber lasers are important for generation of short pulses for future high speed optical time division multiplexed (OTDM) transmission systems. The design and performance of mode locked fiber lasers are described in this talk.

Mode locked fiber lasers use an intracavity modulator. Rational harmonic mode locking technique is used to increase the pulse repetition rate beyond the modulation frequency of the modulator. Rational harmonic mode-locking takes place in a mode-locked fiber laser when modulation frequency fm=(n+1/p)fc, where n and p are both integers, fc is the inverse of the cavity round trip time. 22nd order of rational harmonic mode-locking has been observed when fm * 1 GHz. Optical pulse train with a repetition rate of 100 GHz has been obtained using a modulation frequency fm=10 GHz. Theory of rational harmonic mode-locking has also been developed.

A high quality optical pulse train has been generated at 80 Gb/s using a mode locked fiber laser. The successful operation was achieved via two steps. In the first step, an ultra-stable 2ps (FWHM), 40Gb/s pulse train was generated using the technique of 4th order rational harmonic mode locking. The mode-locked laser was stabilized using a regenerative type base-line extraction feedback technique. In the second step, an external fiber loop mirror consisting of several meters of polarization maintaining fiber was used to double the repetition rate from 40Gb/s to 80Gb/s. The output of 80Gb/s pulse train shows very small pulse to pulse amplitude fluctuation with good long term stability.

Mode locked pulses at two different repetition rates has been generated simultaneously from the same gain medium. These pulses have been stabilized using a phase locked loop. Using soliton compression techniques, pulses with ~ 200 fs pulse width have been generated.

6243-22, Session 5

Passive and active mode-locking of quantum-dot lasers for ultrashort, high-power, and low-noise optical pulse generation

M. Choi, J. Kim, W. Lee, P. J. Delfyett, Jr., College of Optics and Photonics/Univ. of Central Florida

Quantum-dot lasers have shown remarkable properties, such as temperature-insensitive operation, low loss, efficient carrier recombination, ultrafast gain recovery time, suppression of beam filamentation, reduced sensitivity to optical feedback, etc. These excellent performances will contribute to open new cost effective and improved lightwave communication systems. We exploit the performance of mode-locking of quantum-dot lasers for ultrashort, high power, and low noise optical pulse generation using two-section mode-locked laser diodes and a semiconductor optical amplifier (SOA)-based ring laser cavity.

6243-23, Session 5

Wavelength tunable mode-locked quantum dot laser

J. Kim, M. Choi, W. Lee, P. J. Delfyett, Jr., College of Optics and Photonics/Univ. of Central Florida

We demonstrate wavelength tunable quantum-dot mode-locked laser using a two-section device and external grating to generate ultrashort-pulse generation.

The broad gain bandwidths of quantum-dot material make it possible to fabricate very broad wavelength-tunable mode-locked lasers. The saturation of ground state opens a new possibility of using excited state lasing to make mode-locked lasers with even broader tunability.

We will show the performance of the excited state mode-locking, and optimize the device and the system for the tunability.

6243-24, Session 6

Frequency stabilized modelocked laser for photonic signal processing

S. Gee, F. J. Quinlan, S. Ozharar, P. J. Delfyett, Jr., College of Optics and Photonics/Univ. of Central Florida

Frequency stabilized modelocked lasers have recently garnered much attention owing to their potential in metrology, communications, and signal processing applications. The possibility of optical source technology that is economical, compact, and electrically efficient suggests that semiconductor gain media could allow frequency stabilized ultrafast sources to rapidly gain a foothold in communication and signal processing applications. This work will summarize recent work in the area of stabilized modelocked semiconductor diode lasers, and highlight unique features that will impact photonic signal processing applications.

6243-25, Session 6

Supermode noise suppression of a harmonically modelocked laser by external optical injection

F. J. Quinlan, S. Gee, S. Ozharar, P. J. Delfyett, Jr., College of Optics and Photonics/Univ. of Central Florida

We report on supermode noise suppression of a harmonically modelocked laser by optical injection. The modelocked laser was injection locked to a CW narrow linewidth source. Injection locking selects a single supermode group reducing the supermode noise spurs in the photodetected signal by 20 dB to a level of -130 dBc/Hz.

6243-26, Session 6

Semiconductor mode-locked laser intracavity gain dynamics measurements under three wavelength operation

L. C. Archundia-Berra, P. J. Delfyett, Jr., College of Optics and Photonics/Univ. of Central Florida

The intracavity gain dynamics of an external cavity semiconductor hybrid mode-locked laser are measured under three wavelength operation. The results show a partial coherence and a temporal skew between pulses corresponding to different wavelength channels. The temporal skew broadens the temporal pulse profile and the partial coherence decrease the temporal beating between wavelength channels. A measurement of the temporal evolution of the gain shows a slow gain depletion, avoiding nonlinearities, and gain competition between wavelength channels, making multiwavelength operation attainable.

6243-27, Session 6

Photonic crystals: fabrication, modeling, and applications

V. Shklover, L. Braginsky, ETH Zürich (Switzerland)

Different methods of fabrication of photonic crystals from metal oxide, metal or polymer nanoparticles are compared with used in our project template-assisted physical confinement crystallization method. Band structure of different photonic crystals is calculated (including monomodal closest ccp, fcp and bimodal ABx structures) what allows for determination of forbidden light frequencies (photonic gaps) for light propagation in normal and oblique directions in terms of crystallographic directions of photonic crystals (films). The equation of the envelope function of the electric field and boundary conditions for it at the crystal boundaries are used to determine the field before and after the photonic crystals. This makes possible to estimate the crystal (film) transparency for both normal and oblique incidence. The perturbation due to irregularities was taken into account in our calculations in order explain the measured spectra of photonic crystals. The propagation of the light waves in terms of different orthogonal polarizations was considered. Three different limiting cases (models) were analyzed: (1) Model 1 for perfect photonic crystal (film), (2) Model 2 for photonic crystal with short-range irregularities (for example nanoparticles of the same size but different dielectric permittivity), and (3) Model 3 for photonic crystal with long-range irregularities (for example crystals with gradually changing photonic lattice constants). In Model 2, short-range scattering changes the directions of the light propagation, and photons, whose frequencies belong to the gap and whose propagation is forbidden in given crystallographic direction, become allowed in other directions due to scattering. Transparency of such photonic crystal depends on the number of scatterers in the decay length, but is independent on the film thickness. Light propagation in the photonic crystals with long-range irregularities (Model 3), when both scatterers composition and dielectric constant are different, can be described by wave equation with position-dependent effective speed of light. Transparency and dip broadening in transmission spectra depend on deviation of density of photonic crystal. The relevant practical applications comprise filters tunable in required optical range, aircraft IR signature reduction in specific wave length range, reticulated pixel design, using optical readout instead of today's electronic readout, arrays of tunable (and structurally embedded) quasi-1D nanoantennas in devices for target/decoy discrimination, hyperspectral sensors, layered sensor systems in dual-band IR detectors for missile warning systems.

6243-28, Session 7

High-power eye-safe single mode fiber laser for telecommunications and remote sensing

M. E. Gangl, ITT Industries, Inc.

Abstract not available.

6243-29, Session 7

High-power single- and double-frequency tunable mini-laser with nanofilm selector for onboard applications

I. I. Peshko, Univ. of Toronto (Canada); V. Rubtsov, Intelligent Optical Systems, Inc.; J. K. Jabczynski, K. Kopczynski, Wojskowa Akademia Techniczna (Poland)

A new architecture of a single-frequency high efficiency mini-solid-state laser is proposed. The application of a metallic nano-film selector has been investigated theoretically and experimentally. It was shown that a cobalt thin-film selector with a thickness between 8 and 10 nm provides single-frequency output within a power range up to 0.6 W with a 1-mm thick Nd:YVO4 gain crystal. At single-mode operation it was accumulated 85% of the multimode laser output. A slope efficiency of single-frequency oscillation from 41% to 53% has been demonstrated for different crystals. The output coupler movement by piezoceramic transducer provides single-frequency operation, slow smooth tuning, or chirping. Chirping at a repetition rate of 0.5 kHz was achieved. The laser, with a cavity length less than 1", provided smooth tuning up to 10 GHz, frequency chirping up to 4 GHz with a repetition rate about 0.5 kHz, and hop tuning over 150 GHz at a maximum pump power of 1.8 W. Double-frequency operation with a separation of 1.5 to 2.5 GHz was realized in a laser with cavity length up to 100 mm. Physical and technical limitations caused by the wide-gain bandwidth, thermal effects, and mechanical vibrations of the cavity elements are discussed.

6243-30, Session 7

All semiconductor high-power eXtreme chirped pulse amplification system

K. Kim, S. Lee, P. J. Delfyett, Jr., College of Optics and Photonics/Univ. of Central Florida

A proposed method, called “eXtreme Chirped Pulse Amplification(X-CPA)”, to overcome the limitation of small storage energy of semiconductor optical amplifier is demonstrated experimentally and theoretically. Results show an efficient energy extraction, a nonlinear suppression, and an excellent optical signal-to-noise ratio. In addition, we built an all semiconductor X-CPA system using a highly dispersive chirped fiber Bragg grating which possesses 1600ps/nm with 6nm bandwidth at 975nm which generates sub-picosecond optical pulses with \>kW record peak power output at 95MHz.

6243-31, Session 7

Precision laser ranging using eXtremely chirped pulses from chirped fiber Bragg grating

L. Kisimbi, K. Kim, L. C. Archundia-Berra, S. Lee, P. J. Delfyett, Jr., College of Optics and Photonics/Univ. of Central Florida

Spectrally resolved interferometry combining up chirp and down chirp pulses allow for millimeter range resolution in laser ranging applications. Key in our approach is the use of temporally stretched optical pulses of 5 nanoseconds in duration. These stretched pulses were obtained from a femtosecond semiconductor mode-locked laser and were up chirped and down chirped using a chirped fiber bragg grating and recombined to realize spectral interferometry. This approach provides a means to achieve the high pulse energies required for a laser radar application and are easy to achieve using nanosecond pulses but maintains the high spatial resolution associated with femtosecond optical pulses.

6243-32, Session 8

Ultra-wideband photonic control of an adaptive phased array antenna

H. Zmuda, J. Li, P. M. Sforza, Univ. of Florida

This paper presents the optical implementation of a new method for dynamic, adaptive control of a microwave phased array antenna. It is well established that optical signal processing methods provide the antenna array designer with unique capabilities generally not available using conventional microwave techniques. When compared with an all-microwave approach, the utilization of optical components, especially the incorporation of low loss optical fiber, can provide significant reduction in the size and weight of the system as well as providing a high degree of immunity to electromagnetic interference (EMI) and electromagnetic pulse (EMP) effects making them attractive for use with secure communications and in electromagnetically rich environments. More importantly, however, the extremely broad microwave bandwidth generally associated with photonic systems allows for antenna control and processing with RF/microwave bandwidths that are unobtainable using all-microwave processing.

Most optical beamforming systems extant fall into one of two categories; delay-and-sum beamforming and Fourier-based beamforming. Problem posed by these systems include an a-priori knowledge of the exact position of where one wishes to steer the array, precisely specified stable antenna array locations, difficulty in specifying and generating antenna nulls to counteract the effect of interference, and the inability to easily account for atmospheric effects. This paper presents what can be viewed as a paradigm shift in antenna array beamforming with its associated optical implementation. First, an RF pulse is transmitted from any one antenna, with all antennas then set to operate in the receive mode. The backscattered signal(s) from the desired location is captured by each antenna and used to modulate a pulsed laser. An electrooptic switch acts as a time gate to eliminate any unwanted signals such as those reflected from other targets whose range is different from that of the desired transmit/receive location. A chromatic dispersion processor (described in the full paper) is used to extract the exact array parameters of the received signal location. Hence, other than an approximate knowledge of the steering direction, needed only to approximately establish the time gating, no knowledge of the target(s)’s position, and hence no knowledge of the array element time delay is required. The process is repeated at a rate determined by the repetition rate of the pulsed laser source. Target and/or array elements motion is automatically accounted for in the adaptation process while also automatically compensating for atmospheric aberrations.

This paper will present the details of the photonic processor, analytical justification, and simulated as well as preliminary experimental results.

6243-33, Session 8

RF chirp extension via time-division multiplexing

S. Ozharar, S. Gee, F. J. Quinlan, P. J. Delfyett, Jr., College of Optics and Photonics/Univ. of Central Florida

A novel method incorporating time division multiplexing technique with optical parabolic phase modulation has been introduced to overcome the limitations on optical generation of chirped RF signals. Extension of the frequency span and frequency sweep time of a RF chirp signal has been experimentally realized. A chirped RF signal with a center frequency of 100 MHz, frequency span of 20 MHz and sweep time of 200 ns has been generated via this novel method. This chirp signal agrees well with the chirp signal generated by conventional methods.

6243-34, Session 8

A novel nano-injector-based single-photon infrared detector

H. Mohseni, Northwestern Univ.

Interaction of electromagnetic waves with matter is one of the most fundamental processes in our world. While only a physical curiosity several decades ago, this interaction has found ever-increasing practical applications in all aspects of our life. Therefore, detection of extremely weak electromagnetic radiation is becoming the focus of many research works. Single photon detectors (SPD) provide the ultimate limit of such detection in term of sensitivity, and are considered the enabling devices in a wide range of medical, commercial, defense, and research applications. Unfortunately, the existing SPDs have important drawbacks that limit the performance of many systems in the above fields. In particular, these drawbacks have prevented demonstration of the much-needed high-performance SPDs beyond the visible wavelength, and high-performance arrays of SPDs. Many applications can drastically benefit from two-dimensional imaging arrays of SPD, and SPDs that can operate in the longer wavelengths. Some examples are infrared mammography, Infrared tomography, molecular infrared florescent imaging, quantum imaging, infrared non-destructive inspection, and remote detection of buried landmines.

Here a novel single photon detector is presented. The proposed method is based on a nano-injector, and in principle is capable of single photon detection at room temperature. Since the process is not based on avalanche multiplication, the device has no excess noise. Moreover, the device can cover a wide range of wavelengths from UV to mid-infrared, since the detection and amplification processes are completely decoupled and delocalized.Unlike avalanche-based detectors, this device operates at a very low bias that makes it possible to produce large 2D arrays with a good uniformity.

6243-35, Session 8

High-speed wavelength-swept lasers

K. Hsu, Micron Optics, Inc.

High-speed wavelength-swept lasers capable of providing wide frequency chirp and flexible temporal waveforms could enable numerous advanced functionalities for defense and security applications. Powered by high spectral intensity at rapid sweep rates across a wide wavelength range in each of the 1060nm, 1300nm, and 1550nm spectral windows, these swept-laser systems have demonstrated real-time monitoring and superior signal-to-noise ratio measurements in optical frequency domain imaging, fiber-optic sensor arrays, and near-IR spectroscopy. These same capabilities show promising potentials in laser radar and remote sensing applications.

The core of the high-speed swept laser incorporates a semiconductor gain module and a high-performance fiber Fabry-Perot tunable filter (FFP-TF) to provide rapid wavelength scanning operations. This unique design embodies the collective advantages of the semiconductor amplifier's broad gain-bandwidth with direct modulation capability, and the FFP-TF's wide tuning ranges (\> 200nm), high finesse (1000 to 10,000), low-loss (<3dB), and fast scan rates reaching 20KHz. As a result, the laser can sweep beyond 100nm in 25 micro second, output a scanning peak power near mW level, and exhibit excellent peak signal-to-spontaneous-emission ratio \>80dB in static mode. When configured as a seed laser followed by post amplification, the swept spectrum and power can be optimized for Doppler ranging and remote sensing applications. Furthermore, when combined with a dispersive element, the wavelength sweep can be converted into high-speed and wide-angle spatial scanning without moving parts.

6243-36, Session 8

All-optical logic: what can this ambiguous term mean?

H. J. Caulfield, Diversified Research Corp.

The rate of publication of logic papers starting with the words "All optical" doubles every five years. But arguments still break out as to what the term should mean. As electronics is needed to modulate information onto a beam of light and to detect information modulated onto the beam of light, "all optical" cannot refer to the I/O of a system. It must refer only to the logic. I distinguish two types of all-optical logic. The most common type involves covert electronics in crystals, Semiconductor Optical Amplifiers, and the like. The signal stays in the optical domain but is operated upon by some material device in which the electrons (and holes) interact nonlinearly with the light. The second type involves no electronics at all and no interaction at all. It is entirely passive. I illustrate this linear passive all-optical logic here. Finally, I compare both types to suggest which is more appropriate when.

6243-37, Poster Session

Optical variable attenuator based on an double acousto-optic device

G. M. Pacheco, J. E. B. Oliveira, M. A. Pires, Instituto Tecnológico de Aeronáutica (Brazil)

In this paper it presented a review of optical variable attenuation considering the laser light intensity control. Comparing the micro mechanics, MEMS, with the opto-electronics type the most important characteristics of such attenuators are pointed out. Turning the attention to the second type of attenuator the discussion is on the acousto-optic variable attenuator set-ups that enable the variable laser intensity control without change the laser frequency. The analysis of early set-ups take in account the optical mounting, the optical material used in the acousto-optic device and Considering the optical característics of such set-ups it proposed a new acousto-optic device to be used as laser intensity control unit without change the laser frequency. The device has a better mechanical stability, smaller size, easier mounting procedure and lower costs when it is compared with the prevoius acousto-optic variable attenuators. At the end the discussion point out the application of the proposed device for high power laser intensity control and for WDM systems.

6243-38, Poster Session

Optical Ttme-frequency scaling for signal processing applications

C. K. Madsen, A. Chintanpalli, Texas A&M Univ.

Optical time-frequency processing requires a combination of high-speed phase modulators, with a quadratic phase (chirped) response, and quadratic dispersion. The latter is typically achieved using optical fibers or dispersive filters. Time scaling, either dilation or compression, can be achieved using these operations. Time scaling is studied analytically and by simulations to understand the tradeoffs in the number of elements required and residual phase terms. Our goal is to enable efficient scaling operations that can easily be realized using integrated-optic platforms and that can be cascaded. A chirped Fourier transform results from cascading two chirp modulators with an intervening dispersive delay line (or optical filter). Then, a second set of identical elements is needed for the inverse Fourier transform. The overall time-frequency scaling operation requires four modulators and two dispersive elements. An efficient approach is proposed, which reduces the number of required chirp modulators from four to two for this overall operation. The number of dispersive delay lines remains the same, i.e. two are required. Specific relationships are given for "factor of one half" and "factor of two" time scaling. Applications for these efficient scaling operations include wavelet processing and photonic-assisted analog-to-digital conversion.

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6244-100, Session 100

Quantum computing using linear optics and hybrid approaches

J. D. Franson, Johns Hopkins Univ.

Although logic operations are inherently nonlinear, Knill, Laflamme, and Milburn have shown that quantum logic operations can be performed using linear optical elements, additional photons (ancilla), and feed-forward control based on measurements made on the ancilla. We have used techniques of that kind to demonstrate a controlled-NOT quantum logic gate, small-scale circuits, and quantum error correction. Although there has been considerable progress in linear optics quantum computing by a number of groups, the logic operations are probabilistic in the sense that they sometimes fail. A scalable approach to quantum computing must deal with these failure events in some way. One possible approach is to use cluster states, as has been demonstrated recently by the Zeilinger group. Hybrid approaches that combine ion traps or cavity QED with linear optics techniques may also be promising, since the probabilistic nature of the logic operations can be avoided using "repeat-until-success" techniques as suggested by Lim et al. We are considering an all optical solution to the problem in which the quantum Zeno effect is used to suppress the failure events altogether. In the Zeno effect, frequent measurements to determine whether or not an event has occurred can be used to prevent the event from ever occurring. We plan to implement Zeno logic gates by using strong two-photon absorption to inhibit the failure modes of our controlled-NOT logic gates. The status of experiments in these areas will be reviewed.

6244-01, Session 1

Rabi oscillations of inductively isolated Josephson junction qubits

R. M. Lewis, H. Paik, T. A. Palomaki, S. K. Dutta, B. K. Cooper, A. Przybysz, J. R. Anderson, A. J. Dragt, C. J. Lobb, F. C. Wellstood, Univ. of Maryland/College Park

Quantum computation requires a versatile two-level system which can be readily manipulated and whose state can ultimately be read out. We will discuss one such system, an inductively-isolated, current-biased Josephson junction quantum bit (qubit). The inherent strength and limitation of this device is the need for leads which provide for easy qubit control and readout but also couple noise into the device, accelerating quantum decoherence.

Our qubit, an asymmetric dc SQUID, was designed to allow for in situ varying of the filtering on its current leads. We quantify the effect of varying the noise by 3 orders of magnitude by measuring Rabi oscillations. We find that T2, the rate of quantum decoherence, is only weakly effected over this range. In our aluminum junctions in the maximally isolated limit, T2 $\approx$ 20 ns, whereas we measure T2 $\approx$ 10 ns in the poorly isolated limit. We found similar results in niobium devices of similar design. This suggests that current noise on the bias leads is not the primary cause of decoherence for inductively-isolated tunnel-junction qubits.

When two of our qubits are coupled together, we have measured Rabi oscillations of each device. In the maximally entangled limit, T2 is only slightly shorter than in the individual devices, demonstrating the scalability of this qubit.

6244-02, Session 1

Rapid purification and state preparation for a solid state charge qubit

J. F. Ralph, The Univ. of Liverpool (United Kingdom)

This paper discusses the use of continuous weak measurement and quantum feedback for the rapid purification and preparation of the quantum state of a solid state qubit: a superconducting Cooper pair box. The feedback algorithm uses Jacobs' rapid purification protocol, which starts with a completely mixed state and applies controls to rotate the qubit Bloch vector onto the plane orthogonal to the measurement axis. This rotation maximises the average rate of purification of the state but can require large changes in the control fields to produce the required rotation. Since solid state qubits have finite controls and feedback channels have limited bandwidth, such rotations may not be practical. This paper optimises Jacobs' protocol for the Cooper pair box with realistic control fields and combines it with shaped control pulses derived from quantum analogues of classical guidance laws.

6244-03, Session 1

Role of valley-orbital splitting in electron spin dephasing for SiGe quantum dots

Y. G. Semenov, K. W. Kim, North Carolina State Univ.

An electron spin localized in a semiconductor quantum dot (QD) is a natural candidate for a solid-state qubit. When the QD is made of an indirect gap semiconductor with multiple minima near the X points (e.g., Si), the ground and first excited states originate from the valley-orbital doublet whose degeneracy is lifted in the presence of any potential asymmetry in the growth direction. As these two states differ in the values of the g-factor (proportional to the doublelet splitting δ), phonon-induced transitions (with rate $1/\tau$) between them can result in qubit decoherence (with rate 1/T2). Although direct electron-phonon interaction forbids such inter-valley transitions due to the energy/momentum conservation, they become possible when mediated by a random potential of the structure (due, for example, to local lattice deformation, etc.). Our investigation of this spin relaxation mechanism reveals two regimes of decoherence. (i) At a large δ, the inter-valley transitions are fast (compare to T2) and the decoherence is governed by Markovian processes leading to $T2 \sim 1/\tau$. The decoherence for an N qubit-system occurs in time $\Delta t(N) = T2/N$. (ii) When τ exceeds the T2 calculated in Markovian approximation at a small δ, τ approximates the relaxation time for one qubit. The N-qubit system loses the coherence in $\Delta t(N) = \tau/\sqrt{N}$. The prominent extension of N-qubit decoherence time in the latter case ($\sqrt{N}$-reduction factor instead N for Markovian relaxation) stems from the non-exponential probability of quantum transitions (Zeno effect). Numerical estimations in SiGe QDs show importance of the valley-orbital transitions for spin decoherence compared to the spin-flip relaxation at low and moderate magnetic fields.

6244-04, Session 1

Low-order qubit representation for two-dimensional Bose-Einstein condensates (BEC)

G. Vahala, The College of William & Mary; J. Yepez, Air Force Research Lab.; L. L. Vahala, Old Dominion Univ.

Atomic collisions play a critical role in the dynamics of BEC states. At sufficiently low temperatures, since only s-wave scattering between pairs of Bosons is significant, these interactions can be modeled by a pseudo-potential. Moreover, assuming weak interactions, one can represent the ground N-body state by a product state. The resulting dynamics of a

boson in an external potential and in the mean-field potential produced by the (N-1) bosons is the Gross-Pitaevskii (GP) equation. For attractive atomic interactions, a soliton may be formed in a 1D condensate - but in 2D there is a collapse of the condensate if the atomic density exceeds a critical value. Moreover, the dynamics of a BEC in an optical lattice resembles light waves in a nonlinear photonic crystal.

Here, we consider a quantum lattice representation for the 2D GP equation. Only 2 qubits are required per spatial node to represent a scalar component of the GP equation, irrespective of the dimensionality of the system. By appropriate unitary streaming and collision operator sequences one can readily recover the free Schroedinger equation. The nonlinear interactions and any desired external potential can be introduced by a phase factor in the wave function, resulting in the GP equation in the continuum limit. We will also report on trapless BEC in 2D. With no external potential, there is a localized but unstable (Townes) soliton solution which can be stabilized by time-periodic scattering length variations, similar to the stabilization of an inverted pendulum by parametric forces.

6244-05, Session 1

Stability diagram and exchange interaction in coupled quantum dots in magnetic fields

J. Leburton, D. Melnikov, L. Zhang, Univ. of Illinois at Urbana-Champaign

Recently, Hatano et al. were able to extract the exchange interaction between electron spins in laterally coupled vertical quantum dots from the variation of the double-triple point separation in the stability diagram of the structure with applied magnetic fields [1]. The experimental demonstration of the exchange interaction tunability is an important step toward the realization of a C-NOT gate for quantum information processing [2].

In order to gain physical understanding of the parameters influencing the exchange interaction in coupled quantum dots, we obtain theoretically the stability diagram [3] for a two-dimensional model potential using the method of exact diagonalization. In particular, we confirm the qualitative theory and experimental estimates [1,2] that at B = 0, the double-triple point separation decreases with increasing dot separations while the curvature of cell boundaries in the stability diagram increases. For large dot separation, we observe the decrease of the double-triple point separation with increasing magnetic fields applied in the direction perpendicular to the dot plane. This effect is due to the increasing magnetic localization of electrons resulting in the quantum mechanical decoupling of the two dots. We also find the singlet-triplet transition as a function of B, where for large field, the triplet becomes energetically more favorable than the singlet, which is indicated by a corresponding smaller double-triple point separation for the triplet. It is shown that the exchange interaction saturates before the saturation of the double-triple point separation with increasing magnetic fields. Our calculations also give exchange energy values that are significantly smaller than estimates made with the Heitler-London model.

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6244-06, Session 2

Universal dynamical protection of quantum information from decoherence

G. Kurizki, A. G. Kofman, G. Gordon, A. Tal, Weizmann Institute of Science (Israel)

We expound a universal strategy for laser-induced dynamical protection of quantum information. It is designed for entangled mutli-particle systems with arbitrary local coupling to thermal reservoirs, continua or noise sources. The strategy is aimed at preserving the fidelity of any multi-particle state and may help us overcome the main hurdle en route to large-scale quantum-information processing. It employs modulations of the particle (discrete or continuous) energy spectrum by pulses that are tailored to the spectra of the system-reservoir couplings. The modulations are inferred from a universal master equation developed by us [1,2] for arbitrarily driven systems undergoing non-Markovian relaxation: (1) Local control of multi-particle decoherence: To overcome the fragility of multi-particle entangled states field-induced interference between single-particle decoherence channels should impose decoherence-free subspaces. To this end, local variations of the particle-reservoir couplings should be compensated for: instead of the standard “bang-bang” -phase flips, only locally tailored pulse sequences give rise to low multi-particle decoherence. (2) Position- and momentum - decoherence of matter wavepackets. Here the modulations are determined by the spectra of collisional resonances [3].

The dynamical suppression of decoherence of entangled multi-particle states would allow their use as robust carriers of quantum coherence and information, and is a key to understanding the intricacies of the quantum-classical transition.

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6244-07, Session 2

Timescales of decoherence of an open quantum system at low temperatures

V. Privman, Clarkson Univ.; S. Saikin, Univ. of California/San Diego

We consider the time scales for various regimes of bath-mode relaxation and correlations with the system, as the bath drives decoherence of an open quantum system. At low temperatures, the traditional Markovian approximation of the bath modes resetting to thermal instantaneously, without memory of their interaction with the system, is not applicable for times shorter than h-bar/kT. We discuss the robustness of this time scale for low-frequency bath modes when internal bath interactions (anharmonicity) are accounted for.

6244-08, Session 2

Wave function collapse/non-collapse and the representation of classical bits

M. O. Lanzagorta, Naval Research Lab.; J. K. Uhlmann, Univ. of Missouri/Columbia

Quantum teleportation, which takes advantage of the non-locality of entangled quantum systems, has become one of the most important communication protocols in quantum computing. Less known, but equally essential for a variety of applications, are the quantum counting algorithms. Largely based on Grover’s algorithm, quantum counting is a function that returns the number of states in a quantum superposition that satisfy a specific query. In this paper we relate quantum teleportation to the problem of quantum counting. We show that an ability to determine whether there exists a superposition of states associated with a quantum system implies a capacity for superluminal communication, in contradiction to Einstein’s theory of relativity. In particular, within the context of the teleportation protocol, we consider the question of whether Bob can detect if Alice has measured the state of her entangled particle, as well as the meaning of applying a quantum counting algorithm to his entangled state. We also discuss how the answer to these questions may be used to distinguish between certain competing interpretations of quantum mechanics.

6244-09, Session 2

Hyper-entangled two-photon states for quantum communication applications

P. Mataloni, M. Barbieri, F. De Martini, Univ. degli Studi di Roma/La Sapienza (Italy)

Hyper-entangled two photon states have been experimentally realized by a novel method which has been successfully realized in our laboratory in Rome. It allows to generate bi-partite two photon states simultaneously entangled over the degrees of freedom of linear momentum and polarization under excitation of a single, thin Type I, NL crystal in two opposite directions by a UV laser beam [1]. The adoption of these states may represent a useful control in quantum state engineering and Bell state measurements and, more in general, in quantum information applications. For instance, by using hyper-entangled states, one is able to discriminate the entire set of Bell states, either encoded in polarization or momentum qubits. Moreover, suitable experimental schemes in which a polarizing beam splitter acts as a C-NOT gate, with polarization acting as the control qubit and momentum as the target qubit, may be realized.

We'll present some applications of these states, besides their complete characterization and the experimental demonstration of their nonlocal behaviour [2]. Furthermore, by using hyper-entangled photon states, arbitrary qudits states, up to d=4, for quantum key distribution schemes, are generated by means of some additional unitary transformations that can be achieved by customary linear optics [3].

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6244-10, Session 2

Quantum entangled states on a pair of nanotubes

G. A. Gumbs, Hunter College/CUNY

The recent developments in experimental realization of quantum one-dimensional systems such as carbon nanotubes have yielded many interesting features in both their transport and optical properties.

Some experiments have shown that a gate voltage applied perpendicular to the axis of the nanotube can lead to spin-orbit interaction (SOI).

This is of the same nature as the Rashba-Bychkov SOI at a heterojunction formed by two semiconductors. Using a simple nearly-free-electron model, we obtain analytical expressions for the energy bands for electrons on the surface of nanotubes in the presence of SOI. The simplified calculation we used was able to show that the SOI splits each energy level into two subbands which could then be used to accommodate the two types of spin. We employ these results to determine the exchange interaction and subsequently the entanglement of electrons on a single-walled and double-walled nanotube as well as parallel nanotubes.

6244-13, Session 2

Collapse and revival of entanglement of two interacting qubits

V. S. Malinovsky, MagiQ Technologies, Inc.

A new method of entangled states preparation of two-qubit systems is proposed. The method combines the techniques of coherent control by manipulation of the relative phase between pulses, and adiabatic control using time-delayed pulse sequences.

In this work we exploit the sensitivity of population dynamics to the relative phase of the fields in order to control entanglement. The interplay between adiabatic partially time-delayed pulse sequences and phase control allow to prepare any type of entangled state in a simple and robust manner. We show that the population and entanglement exhibits collapses and full revivals when the initial distribution of phonons is a coherent state. A scheme to generate phase-controlled two-qubit gates based on the effect of full revivals is proposed.

6244-14, Session 2

Incoherent control and entanglement for two-dimensional coupled systems

R. Romano, D. D'Alessandro, Iowa State Univ.

We investigate accessibility and controllability of a quantum system S coupled to a quantum probe P, both described by two-dimensional Hilbert spaces, under the hypothesis that the external control affects only P. In this context accessibility and controllability properties describe to what extent it is possible to drive the state of the system S by acting on P and using the interaction between the two systems. We give necessary and sufficient conditions for these properties and we discuss the relation with the entangling capability of the interaction between S and P. In particular, we show that controllability can be expressed in terms of the SWAP operator, acting on the composite system, and of its square root.

6244-15, Session 3

Verification of the ARL quantum key distribution testbed

G. H. Stolovy, Army Research Lab.

The operation of a polarization-based quantum key distribution (QKD) testbed system is described. The system was developed for the Army Research Laboratory (ARL) by the Johns Hopkins Applied Physics Laboratory under the DARPA Quantum Information Science and Technology program. Recent developments include upgrading the testbed system for operation at 830 nm wavelength.

We describe the system architecture, control software, diagnostic and operational modes. The cryptosystem was tested in a point-to-point configuration with transmitter and receiver separated by a distance of 1.5 km, and using in-ground single-mode telecommunications fiber for the quantum channel.

6244-16, Session 3

Entangling probes of QKD

H. E. Brandt, Army Research Lab.

The quantum circuits and designs are reviewed of two different optimized entangling probes for attacking the BB84 protocol of quantum key distribution (QKD), both extracting maximum Renyi information on the prepivacy amplified key. In both devices, probe photon polarization states become optimally entangled with the signal states on their way between the legitimate transmitter and receiver.

6244-17, Session 3

Quantum cryptography at 830 nm in standard telecommunications fiber

B. C. Jacobs, S. Hendrickson, M. Dennis, J. D. Franson, Johns Hopkins Univ.

Quantum cryptography is a rapidly maturing technology for the transmission of secure information based on the fundamental laws of nature. There are now commercially available systems that can operate over relatively long distances (~50km) in standard telecommunications fiber (e.g. SMF28) by taking advantage of the low transmission losses at 1.3 or 1.5 microns

in these fibers. Although there has been much progress toward the development of highly efficient and low-noise detectors for these wavelengths, silicon avalanche photodiodes currently offer superior single photon counting performance, but only at visible and near IR wavelengths where the fiber transmission is poor. Because the overall throughput or key generation rate of a Quantum Key Distribution (QKD) system depends on both the fiber loss and the detection characteristics, it is possible to calculate the optimum operating wavelength given a target link distance. For ranges typical of local area networks (<5km), a QKD system operating below 850nm may be optimal, even though standard telecommunications fiber supports multiple optical modes at these wavelengths. We have recently developed an optical mode filter that allows efficient coupling into, and higher order mode rejection from SMF28 fiber at 830nm. We have used these filters to launch and recover QKD signals from a polarization-based QKD system implementing the complete BB84 protocol. Here we present results from testing and operation in installed fiber links ranging up to 4km that demonstrate that the filters can attenuate the higher order modes over 35dB while having a minimal (<1dB) impact on the fundamental mode carrying the QKD signal.

6244-18, Session 3

Is quantum key distribution provably secure?

T. Nakassis, J. C. Bienfang, P. Johnson, A. Mink, P. Rogers, X. Tang, C. J. Williams, National Institute of Standards and Technology

The security of Quantum Key Distribution (QKD) depends on our ability to derive meaningful and reliable probabilistic bounds on the amount of information that can be extracted through Quantum-channel tampering and Reconciliation monitoring (hence lower bounds on the residual Entropy after Reconciliation). The paper examines the joint evolution of the tampering models proposed and of the machinery that produces high probability residual Entropy bounds. The extant theory isolates the two sources of information leakage, treats each of them as the outcome of a random experiment, establishes probabilistic bounds for each source, and bounds the total information leakage through an additive process. We show that in one instance of practical interest while quantum memories do not exist(measure-resend attacks and interactive Reconciliation), the resulting bound is incorrect, overestimates the residual entropy, and compromises the outcome of Privacy amplification. We conclude that, at least in this instance, the Reconciliation mechanism systematically drives the process towards the low probability events that the Entropy estimation theorems dismissed as being of inconsequential probability. Therefore, we conclude that the security of QKD is, and will remain, unproven for as long as we cannot assess if and to what extent the information exchanged during the Reconciliation process matches the assumptions of the theorems used to bound the residual Entropy.

6244-19, Session 3

Quantum cryptography on multi-user network architectures

P. D. Kumavor, E. J. Donkor, A. Beal, S. Yelin, B. C. Wang, Univ. of Connecticut

Quantum cryptography allows two parties to communicate via an ultra-secure link whose security is guaranteed by the laws of quantum mechanics rather than mathematical complexity, thus making it unconditionally secure even against advances in efficient computational algorithms. In quantum cryptography, or more commonly quantum key distribution (QKD), the users first attempt to share a secret key. This is done by encoding the values of the keys unto single photon states in two non-orthogonal bases. Heisenberg's uncertainty principle does not allow one to make simultaneous measurements in both bases to an arbitrary degree of precision; hence the photon states carrying information about the cryptographic keys remain secure.

Quantum key distribution has developed from its infancy when it was just a theoretical curiosity to a point where a fully functional two-user QKD system is commercially available (e.g. Magic Tech Inc.). One key requirement for widespread usage in a practical environment is the expansion of such two-user systems to more users. Another is the ability of a QKD network to co-exist with existing network infrastructures; research work is making steady strides in these areas. This paper models the performance of three common network architectures namely the star, ring, and bus, when used for sending cryptographic keys. The quantum bit error rate (QBER) of the QKD link between the network server and users is used in accessing the suitability of each of the architectures in providing secure communication. The paper also presents a proof-of-principle experimental result showing the feasibility of implementing a multi-user QKD network.

6244-20, Session 3

Matrix optimizations for quantum communications

J. M. Myers, H. M. Shen, T. T. Wu, Harvard Univ.

We discuss some problems of quantum communicatons, in which one seeks a positive operator-valued measure (POVM) to optimize the reception of a transmitted quantum state. We introduce and solve the optimization problem for a novel criterion and show how it generalizes the more usual criteria. This is accomplished by use of a vector-space basis reciprocal to that of the possible transmitted states. In addition, solutions already known for two usual criteria are derived more efficiently.

6244-21, Session 3

Secure communication with entangled photons

A. S. Trifonov, MagiQ Technologies, Inc.

The recent progress in quantum cryptography and quantum communication urge on the development of practical schemes based upon the single/entangled photons. In this talk the progress in development of such sources will be presented. Currently our approach allows secure communication over 100 km of optical fiber; the perspectives for longer distances will be overviewed.

6244-22, Session 4

High speed quantum key distribution system supports one-time pad encryption of real-time video

A. Mink, X. Tang, National Institute of Standards and Technology

NIST has developed a complete quantum key distribution (QKD) system to support high-speed QKD over both free-space and optical fiber. NIST's approach to high-speed QKD is based on a synchronous model and hardware support. This has greatly improved overall key generation rate as more of the software protocols are moved to hardware. Currently the system is generating sifted key at a rate in excess of 2 Mb/s with an error rate of about 3%. The current system is limited by the detected single photon rate, while the hardware capacity for sifting keys is about 50 Mb/s. Reconciled and privacy amplified key is being generated by software at about 1 Mb/s for the current sifted rate. If the sifted key rate increases, this software implementation can easily be speeded-up by using parallel processing over multiple processors because of the coarse granularity of each process. A hardware implementation of the reconciliation and privacy amplification algorithms, which is currently underway, is estimated to have the capacity of up to 20 Mb/s of secret key. A one-time pad encrypted surveillance video application serves as a demonstration of the speed, robustness and sustainability of the NIST QKD system. Plans for quantum networks are currently underway. We will discuss our infrastructure, both hardware and software, it operation and performance along with our migration to quantum networks.

6244-23, Session 4

Post-quantum Diffie-Hellman key exchange

X. Li, M. M. Anshel, City College/CUNY

We argue a little bit of teleportation which can make conventional Diffie-Hellman post-quantum cryptosystem. Post-quantum cryptosystem can be used for securing information exchange, dis-spy the use of powerful quantum code breaking algorithms. We explore the question of how much a teleportation is enough for Diffie-Hellman Key Exchange.

6244-24, Session 4

Practical implementation of continuous-variable quantum key distribution

T. Hirano, A. Shimoguchi, K. Shirasaki, S. Tokunaga, A. Furuki, Gakushuin Univ. (Japan); Y. Kawamoto, Sony Corp. (Japan); R. Namiki, Osaka Univ. (Japan)

Recently there have been a growing interest in continuous-variable quantum key distribution (CV-QKD) using coherent states. In CV-QKD a faint light is detected by homodyne detector that can operate close to the theoretical limit at room temperature. Therefore, generation and detection of the signal in CV-QKD can be performed near ideally even with today's technology. We have proposed CV-QKD using coherent states and post-selection and demonstrated a prototype experiment (PRA 68, 042331(2003), theoretical analysis can be found in PRA 72, 024301 (2005) and references therein). However practical implementation of CV-QKD has little studied so far. In this paper, we report "plug and play" implementation using an optical fiber and free space implementation of CV-QKD. In homodyne detection, we use a local oscillator (LO) in order to detect a weak signal, and the LO is much stronger than the signal (typically 10^6 : 1). In conventional plug and play (or auto compensating) systems, two pulses traverse an identical optical path and the intensities of them become equal. In our experiment we use an acoust optic modulator and have successfully controlled the intensities of the signal and the LO. For free space implementation of CV-QKD the stability of the double interferometer is a crucial problem. Exploiting birefringence of an EOM crystal we have separated the signal and LO in time longer than the coherence time of the pulses. In this setup the signal and LO traverse along the same ray path, so the stability of the interferometer is greatly improved. Details of QKD experiments will be reported.

6244-25, Session 4

Auto-compensated polarization coding fiber-based quantum key distribution system operating at sifted key-rate over 4Mbit/s

X. Tang, L. Ma, A. Mink, National Institute of Standards and Technology

NIST has developed a quantum key distribution (QKD) system based on polarization coding in optical fiber, while using the same infrastructure from it free-space based QKD system. Two channels are used in the system: a unidirectional quantum channel and a bi-directional classical channel. The quantum channel operates at 850 nm and the classical channel operates in the 1510 and 1590 nm. Through wavelength division multiplexing these channels share a single commercial telecom fiber1 km in length. Computer-automated polarization controllers are incorporated in the design to automatically compensate for polarization variation in the optical fibers that are caused by stress, temperature changes and birefringence. We will discuss our current design, which has achieved a sifted key rate of 2 Mb/s with a 3% error rate and a mean photon number of 0.1. We will present models of our APDs performance and measurements of system jitter and show its relationship to sifted key rates. Finally we will discuss plans for enhancements that will lead to increasing our sifted key rate from 2 Mb/s to 4Mb/s while maintaining the current low error rate of between 1% and 3% as well as our plans for QKD networks.

6244-26, Session 5

Noise and disturbance in quantum measurements and operations

M. Ozawa, Tohoku Univ. (Japan)

Heisenberg's uncertainty principle has been understood to set a limitation on measurements; however, the long standing mathematical formulation established by Heisenberg, Kennard, and Robertson does not allow such an interpretation. Recently, a new relation was found to give a universally valid relation between noise and disturbance in general quantum measurements [M. Ozawa, Phys. Rev. A 67, 042105 (2003)], and it has become clear that the new relation plays a role of the first principle to derive various quantum limits on measurement, information processing, and security of quantum channels in a unified treatment. In this talk, we revisit the foundations of the above noise-disturbance relation. The above relation was formulated for the root-mean-square (rms) distance between the observable to be measured and the probability operator valued measure (POVM) actually used. The usefulness of this formulation has already been clear from various applications; however, there is a foundational problem. The rms distance is dominating but not perfect in the sense that positive error implies the impossibility of a precise measurement in that state but zero error does not necessarily imply the possibility, although the general notion of precise POVM measurement has not been established. Here, we discuss the notion of precise POVM measurements of a given observable in a given state in the light of modal interpretation of quantum mechanics, and considers the class of perfect distances. Then, we shall show that even in the perfect error notions the product of position measuring noise and momentum disturbance can be arbitrarily small but it is possible to generalize the noise-disturbance uncertainty relation to perfect error distances.

6244-27, Session 5

Measurement of single-spin state for quantum computation based on optically detected methods

M. E. Hawley, G. W. Brown, G. Berman, B. Chernobrod, Los Alamos National Lab.

The main problem in all recent solid-state quantum computer (QC) proposals based on single spin as a qubit has been the inability in on system to create a spin quantum device, control the spin interactions, and demonstrate simple quantum gates by measuring the results the operations, i.e. measuring the spin state of even a small number of spins let alone a single spin. Recent approaches based on MRFM, STM, tunneling effects in quantum dots all suffer from non single spin resolution, long measurement times, and destruction of the spin state. Here we suggest a couple of novel approaches for measurement of qubit states based optical techniques. The novel aspect of our approach is the combination of STM fabrication proposed in the Kane approach, NMR spin manipulation methods, and optical readout methods. One readout methods involves the use of photoluminescence spectroscopy of excitons while another involves using a scanning ODMR probe for readout Our approach directly addresses the need for a spin readout method for spin measurement called out as a goal in the quantum information science and technology roadmap section. The ultimate goal is to integrate this readout system into one that allows manipulation of individual qubits.

6244-28, Session 5

Quantum weak measurements and complexity classes

D. Ghoshal, George Mason Univ.

We are investigating the impact of Time-Symmetrized quantum theory on quantum computing. The recent result of quantum computing illustrates that if "post-selection" of measurement is provided, the class of problems efficiently solvable by quantum computer is the same class as proba-

bilistic polynomial in classical complexity theory. After reviewing this result we are exploring the ideas to NP class of problems and discuss our findings. Our critical approach of study in this area is to clarify the consequences of weak measurements in the field of complexity theory - quantum or classical complexity classes.

6244-29, Session 6

Scheduling physical operations in a quantum information processor

T. S. Metodiev, D. Thaker, Univ. of California/Davis; A. Cross, Massachusetts Institute of Technology; F. T. Chong, Univ. of California/Santa Barbara; I. L. Chuang, Massachusetts Institute of Technology

Irrespective of the underlying technology used to implement a large-scale quantum information processor, one of the central challenges of architecture designers is the ability to map and schedule a quantum application onto a physical grid by taking into account the cost of communication, the classical resources, and the maximum parallelism that can be exploited, while preserving the fault-tolerant properties of the architecture. In this paper we introduce and evaluate a physical quantum operations scheduler which accepts a description of a quantum application together with a physical layout description and outputs a sequence of instructions that include the required qubit-qubit communication.

The scheduler we introduce takes advantage of the fixed structure of the physical layout and the initial placement of the qubits. It works in four major stages, which are repeated until the schedule is complete: 1) separation of sources and destinations, 2) source path extraction, 3) source path placement, and 4) stall cycle reduction. The first stage uses a set of constraints to disambiguate between source qubits and destination qubits. The second stage draws the source qubit paths and chooses a number of distinct paths equal to the number of parallel gates available at a given cycle of execution using the application's control flow graph. The third stage inserts the paths in the output schedule. Finally, the stall cycle reduction optimizes the execution time with consideration for the available set of classical resources. We use the physical operations scheduler to calculate the classical resource requirements, the available parallelism, and the running time for logical gates encoded with the Steane [7,1,3] Hamming code, the [21,3,7] Golay error correction code, and error-correcting teleportation.

6244-30, Session 6

Two-dimensional optical cluster states

G. N. Gilbert, M. Hamrick, Y. Weinstein, The MITRE Corp.

We demonstrate a method of creating optical two-dimensional cluster states. We exploit certain characteristics inherent in cluster states to make our scheme more efficient than other fusion based optical constructions.

6244-31, Session 6

Information theoretic connotation to the Grover algorithm

R. C. Venkatesan, Systems Research Corp. (India)

The relation between the Fubini-Study metric and the Fisher information measure, and, geodesics on the Fubini-Study metric and the minimization of the Fisher information are established for continuous variables. The Grover iteration is demonstrated to traverse geodesics of a Fubini-Study metric defined in quantum Hilbert space. The traversals are parameterized in terms of the computer time. The framework for a Fisher game played between an observer and the system under measurement is established. The Fisher game is demonstrated as being represented by a generic Schrödinger-like equation possessing a pseudo-potential comprising of constraint terms representing the observed parameters. An uncertainty principle for estimation of the constraint terms, similar to the Anandan-Aharanov uncertainty relation, is established. The implication of "intelligent states" (the equality limit of the uncertainty relation) to the Grover iteration is exemplified within the context of the minimum mean square error criterion. A Schroedinger-like equation describing the minimum Fisher information connotation of the Grover iteration for lattice variables is derived, employing a lattce variational principle inspired by T. D. Lee. Physically signifiicant similarities and distinctions between the continuous and lattice models are discussed within the context of the Grover iteration. Next, the case of Shor factorization with a Grover loop is studied. Numerical examples for exemplary cases are presented.

6244-32, Session 6

Quantum image compression

G. F. Chapline, Jr., Lawrence Livermore National Lab.

In a material which possess a quantum order parameter with a critical point, variations in the order parameter can represent either classical or quantum information depending on how close one is to the critical point. As a consequence one can change classical information into quantum information and vice versa by controlling how close one is in either parameter space or spatial distance from quantum critical conditions. As an application of this idea we consider the practical possibility of encoding the information in a classical 2-d image into the phases of an entangled quantum state; thereby achieving exponential compression.

6244-33, Session 6

Quantum network addressing method and expandable quantum router

Z. Han, Univ. of Science and Technology of China (China)

For any network, addressing is necessary. Here we shows a kind of addressing method to find an appointed node in a fiber net, by which we can send an encoded photon to a given node according to its wavelength and which node it comes from. According this method, a typical topological structure was designed for quantum key distribution network, which was named as "quantum router" by us. It is easy to illuminate that the node numbers of the "quantum router" should be expandable if we have enough discrete wavelength. For a "quantum router" with N nodes, we need only N-1 discrete wavelength to setup a "quantum router" if N is even or N discrete wavelength when N is odd number. In order to join the network, each user should be connected to a node of the "quantum router" with fiber, and then he can communicate to any users in the network at the same time. Based on this "quantum router", a four users Quantum Key Distribution network has been established in Lab, the measurement revealed that there is very weak cross talking between any two users.

6244-34, Session 7

Spin networks and anyonic topological computing

L. H. Kauffman, Univ. of Illinois at Chicago; S. J. Lomonaco, Jr., Univ. of Maryland/Baltimore County

This talk will give a concise derivation of topological quantum field theoretic models of quantum computing.

We utilize the knot theoretic models for topological quantum field theory that are derived from q-deformed spin networks and the Temperley-Lieb algebraic approach to the colored Jones polynomials.

6244-35, Session 7

Topological quantum computing and the Jones polynomial

S. J. Lomonaco, Jr., Univ. of Maryland/Baltimore County; L. H. Kauffman, Univ. of Illinois at Chicago

The talk begins with a description of the Aharanov-Jones-Landau (AJL) quantum algorithm which, for given epsilon, computes in polytime epsilon-approximations of the values of the Jones polynomial at roots of unity, with exponentially small probability of failure. We then show how this algorithm can be naturally transformed into a polytime quantum algorithm that exactly computes the Jones polynomial also with exponentially small probability of failure. Finally, we show that this transformed algorithm is numerically unstable. This suggests that the AJL quantum algorithm cannot compute the Jones polynomial on a physical quantum computer in polytime.

6244-36, Session 7

Applications of the quantum computer condition

G. N. Gilbert, M. Hamrick, J. Thayer, The MITRE Corp.

We describe a new unified theoretical framework that describes the full dynamics of quantum computation. Our formulation allows any questions pertaining to the physical behavior of a quantum computer to be framed, and in principle, answered. We refer to the central organizing principle of the formulation, on which our theoretical structure is based, as the Quantum Computer Condition (QCC), a rigorous mathematical statement that connects the irreversible dynamics of the quantum computing machine, with the reversible operations that comprise the quantum computation intended to be carried out by the quantum computing machine. Armed with the QCC, we derive a powerful result that we call the Quantum Computer No-Go Theorem. This theorem gives a precise mathematical statement of the conditions under which fault-tolerant quantum computation becomes impossible in the presence of dissipation and/or decoherence. In connection with this theorem, we explicitly calculate a universal critical damping value for fault-tolerant quantum computation. In addition we show that the recently-discovered approach to quantum error correction known as “operator quantum error-correction” is a special case of our more general formulation. Our approach furnishes what we will refer to as “operator quantum fault-tolerance.” In particular, we show how the QCC allows one to derive error thresholds for fault tolerance in a completely general context. We prove the existence of solutions to a class of time-dependent generalizations of the Lindblad equation. Using the QCC, we also show that the seemingly different circuit, graph- (including cluster-) state, and adiabatic paradigms for quantum computing are in fact all manifestations of a single, universal paradigm for all physical quantum computation.

6244-37, Session 7

Information accessible by measurement in mirror-symmetric ensembles of qubit states

M. R. Frey, Bucknell Univ.

We formulate an expression for the accessible information in mirror-symmetric ensembles of real qubit states. This general expression is used to make a detailed study of optimum quantum measurements for extracting the accessible information in three-state, mirror-symmetric ensembles. Distinct measurement regimes are identified for these ensembles with optimal measurement strategies involving different numbers of measurement operators, similar to results known for minimum error discrimination. Specifically, we identify two generic measurement regimes in which fixed two-projector, von Neumann measurements are optimal. Between these regimes we find a transitional regime requiring three measurement operators. The optimal operators in this regime vary with the parameters of the ensemble. These results extend and unify known results for the accessible information in two pure states and in the trine ensemble.

6244-38, Session 7

Improved algorithmic cooling for scalable NMR quantum computers

A. Kaltchenko, Wilfrid Laurier Univ. (Canada) and Univ. of Waterloo (Canada)

The scaling[1] of NMR ensemble computers is currently one of the main obstacles to building larger-scale quantum computing devices. To achieve scalability, one needs a large number of highly polarized spins in liquid nuclear-spin systems at finite temperature. In quantum computing terminology, such spin-half states are (almost) pure qubit states. Producing highly polarized spins (almost pure qubit states) out of non-polarized spins (non-pure qubit states) is sometimes called[2] “purification “. From a thermodynamic point of view, purification can be viewed as cooling spins to a very low temperature.

PREVIOUS RESULTS:

An interesting compression-based algorithmic cooling (via polarization heat bath) was proposed in [1]. A compression subroutine used in [1] is capable of producing m pure qubits out of n non-pure qubits, where m is upper-bounded by the expression n*[1 - H(1/2 +eps/2)] . Here H(.) is the binary entropy function, and eps arises from the qubits’ density matrix as follows. The qubit state is given by a diagonal 2x2 matrix with the diagonal elements (1+eps)/2 and (1-eps)/2. The value of eps can be viewed as some measure of non-purity and is ranging from 0 for a totally non-pure (mixed) state, to 1 for a pure state. For large n, m is approximated by [(eps^2)/2ln2]*n. Given that eps is typically equal to 0.01, m is approximated by n*7x10^(-5).

OUR CONTRIBUTION:

We point out that the compression subroutine in [1] is not capable of utilizing the correlation between individual qubits. We present a new compression subroutine, which does utilize the higher order[3] correlations between the m initial qubits. This leads to the improvement of the upper bound for m as follows n*[1 - H(higher-order)], where H is the so-called second- or higher order Shannon entropy. It is easy to see that H(higher-order) is always less or equal than H(1/2 +eps/2). For liquid nuclear-spin systems, we expect a considerable gain as we estimate H(higher-order) to be twice less than H(1/2 +eps/2).

[1] P. Boykin, T. Mor, V. Roychowdhury, F. Vatan, and R. Vrijen, “Algorithmic cooling and scalable NMR quantum computers”, Proc. Natl. Acad. Sci., Vol. 99, No. 6, pp. 3388—3393, USA, 2002.

[2] I. Devetak, “Distillation of local purity from quantum states”, LANL e-print: quant-ph/0406234, 2004.

[3] A. Kaltchenko and E.-H. Yang, “Universal Compression of Ergodic Quantum Sources,” Quantum Information and Computation, Vol. 3, No 4, pp. 359—375, 2003.

6244-40, Session 8

Quantum query complexity in computational geometry

A. A. Bahadur, Indian Institute of Technology Bombay (India); C. Durr, Univ. Paris-Sud II (France); R. Kulkarni, The Univ. of Chicago; T. Lafaye, Univ. Paris-Sud II (France)

We are interested in finding quantum algorithms for problems in area of compatational geometry. But since input sizes are large quadratic running times are often not good enough. Bounded error quantum algorithms have sublinear running times.

To our knowledge there are two works on this subject. One is by K. Sadakane , N Sugawara , T. Tokuyama and the other by W Smith. These however do not contain lower bounds.

The main quantum ingredient in their algorithms is a quantum algorithm for the Element Distinctness problem based on Grover’s Search. We revisit the problems using the recent quantum algorithm for element distinctness based on quantum walk. We also show new lower bounds and study new problems, in particular on polygons and the 3-Sum problem.

6244-41, Session 8

Algorithm for symbolic computation of universal gates from Yang-Baxterization

J. F. Ospina, M. E. Vélez, Univ. EAFIT (Colombia)

At the present time it is had at least five models of quantum computation: standard, adiabatic, hybrid, geometric and topological. The first four models are constructed from local degrees of freedom whereas the last one is it on global degrees of freedom. Some people think that this last characteristic could get to be crucial for the efficient implementation of the quantum computers. Within the model of topological quantum computation, it is possible to distinguish two lines of formulation: a denominated line Kitaev-Freedman et al (KF) and the other denominated line Kauffman-Lomonaco et al (KL). In KF line the topological quantum field theories are used to construct topological modular functors, that allow to design universal quantum gates. In the KL line the relations between the topological entanglement and the quantum entanglement are used to construct the universal gates, by means of Yang-Baxterization of the braid relations. The objective of the presentation is to show a certain algorithm in computer algebra that allows to make the process of Yang-baxterization and the symbolic computation of universal gates such as the CNOT gate. We hope that the presentation can be of interest for the community of the quantum computation interested in topological quantum computation. Also it is tried to as much show some open fronts of investigation in the KL line as in the KF line.

6244-42, Session 8

Generalization of some hidden subgroup algorithms for input sets of arbitrary size

D. Poslu, A. C. Say, Bogaziçi Univ. (Turkey)

We consider the problem of generalizing some quantum algorithms so that they will work on input domains whose cardinalities are not necessarily powers of two. When analyzing the algorithms we assume that generating superpositions of arbitrary subsets of basis states whose cardinalities are not necessarily powers of two perfectly is possible. We have taken Ballhysa's model as a template and have extended it to Chi, Kim and Lee's generalizations of the Deutsch-Jozsa algorithm and to Simon's algorithm. With perfectly equal superpositions of input sets of arbitrary size, Chi, Kim and Lee's generalized Deutsch-Jozsa algorithms, both for evenly-distributed and evenly-balanced functions, worked with one-sided error property. For Simon's algorithm the success probability of the generalized algorithm is the same as that of the original for input sets of arbitrary cardinalities with equiprobable superpositions, since the property that the measured strings are all those which have dot product zero with the string we search, for the case where the function is 2-to-1, is not lost.

6244-43, Session 8

A note on the Schroedinger coordinate-wave function duality and information geometry

R. C. Venkatesan, Systems Research Corp. (India)

The coordinate- wave function duality of the Schroedinger equation [1] is established for the case of a pseudo-potential comprising of experimental observables.

Observables satisfying the uncertainty relation for "intelligent states" [2], is examined in detail.

A Hamilton-Jacobi formulation incorporating the Legendre equivalence/duality is derived.

The model is extended to cases where the wave function (probability amplitudes) and the observables are parameterized by time. The effect of the Legendre equivalence/duality in re-defining information geometric metrics, notably the Fubini-Study metric [3] is examined.

The case corresponding to the minimum Fisher information criterion, which requires that the wave function evolves along a geodesic on a Fubini-Study metric defined in Hilbert space, and, satisfy the Jacobi equation, is studied within the framework of the Legendre duality.

The practical utility of the present study to the Grover optimal search algorithm, and selected topics in pattern recognition and exploratory data analysis is discussed. Numerical examples for exemplary cases are presented.

[1] A. Faraggi, and, M. Matone, "Duality of x and psi in Quantum Mechanics", Phys.Rev.Lett. 78, 163, 1997

[2] N. Horesh, and, A. Mann, "Intelligent States for the Anandan-Aharonov Parameter Based Uncertainty Relation", J. Phys. A. (Math. Gen.), 31, L609-L611, 1998.

[3] S. L. Braunstein, and, C. M. Caves, "Statistical Distance and the Geometry of Quantum States" Physical Review Letters 72, 3439-3442, 1994.

6244-44, Poster Session

Geometric phase gate with a quantized driving field

J. R. Gea-Banacloche, S. Siddiqui, Univ. of Arkansas

Geometric quantum logical gates have been reported to be, under some conditions, less sensitive to noise in the control parameters than ordinary dynamical gates. In this work, we consider a geometric, adiabatic phase gate, in which the electromagnetic field used to drive the qubit evolution (a radio frequency field, for instance) is quantized, and investigate how this affects the gate performance. We note that, because the phase gate commutes with the z component of the spin, the "conservation-law induced quantum limit", or CQL, recently discussed by Ozawa and Gea-Banacloche (J. Opt. B.: Quantum Semiclass. Opt., 7, S326-S332, 2005) places no constraints, in principle, on the accuracy achievable under these conditions. Nevertheless, using a quantized multimode description, we find that, in general, the field becomes entangled with the atoms, with the entanglement being largest for the initial qubit states that are changed the most by the logical operation. We calculate how the error probability due to this effect depends on the field strength, for various kinds of initial field states.

6244-46, Poster Session

Finite temperature quantum logic

D. Ghoshal, R. B. Gomez, George Mason Univ.; M. O. Lanzagorta, Naval Research Lab. and ITT Industries and George Mason Univ.; J. K. Uhlmann, Univ. of Missouri/Columbia

The engineering of practical quantum computers faces the so-called "temperature mismatch problem". That is, quantum logic using ensembles of quantum systems require very low temperatures, $kT \ll E$, where T is the temperature, k is the Boltzmann constant, and E is the energy separation used to represent the two different states of the qubits. On the other hand, the electronics necessary to control these quantum gates are designed for much higher temperatures. One solution to this problem is to construct electronic components that are able to work at very low temperatures, but the practical engineering of these devices continues to face many difficult challenges. Another proposed solution is to study the behavior of quantum gates at finite temperature. This is also a nontrivial task, as the dynamics of quantum systems at finite temperature is radically different from the T=0 case, where collective interactions and stochastic phenomena are not taken into consideration. In this paper we discuss several aspects of quantum logic at finite temperature. That is, we present our analysis of the behavior of quantum systems undergoing a specified computation performed by quantum gates at nonzero temperature. Our main interest is the effect of temperature on the practical implementation of quantum computers to solve potentially large and time-consuming computations.

6244-47, Poster Session

Toward the manipulation of a single spin in an AlGaAs/GaAs single-electron transistor

S. Amasha, D. M. Zumbuhl, K. MacLean, I. Radu, M. A. Kastner, Massachusetts Institute of Technology; M. P. Hanson, A. C. Gossard, Univ. of California/Santa Barbara

Single-electron transistors (SETs) are attractive candidates for spin qubits. An AlGaAs/GaAs SET consists of a confined two-dimensional droplet of electrons, called an artificial atom or quantum dot, coupled by tunnel barriers to two conducting leads. Controlling the voltages on the lithographic gates that define the quantum dot allows us to confine a single electron in the dot, as well as to adjust the tunnel barriers to the leads. By applying a magnetic field, we can split the spin-up and spin-down states of the electron by an energy |g|\mu_{B}B; the goal is to utilize coherent superpositions of these spin states to construct a qubit. We will discuss our attempts to observe Rabi oscillations in this system by applying magnetic fields at microwave frequencies. Observation of such oscillations will demonstrate that we can manipulate a single spin and allow us to measure the decoherence time T_{2}.

Conference 6245: Optical Pattern Recognition XVII

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6245-01, Session 1

MSTAR 10-Class classification and confuser and clutter rejection using SVRDM

C. Yuan, Siemens Corporate Research; D. P. Casasent, Carnegie Mellon Univ.

We compare the performance of our SVRDM (support vector representation and discrimination machine, a new SVM classifier) to that of other popular classifiers on the moving and stationary target acquisition and recognition (MSTAR) synthetic aperture radar (SAR) database. We present new results for the 10-class MSTAR problem with confuser and clutter rejection. Much prior work on the 10-class database did not address confuser rejection. In our prior work [1], we presented our results on a benchmark three-class experiment with confusers to be rejected. In this paper, we extend results to the ten-class classification case with confuser and clutter rejection. We use clutter chips which resemble real targets. Our SVRDM achieved perfect clutter rejection scores. Energy-normalization, which was used in many prior algorithms, makes clutter chips similar to target chips and thus produces worse results. We do not energy-normalize data.

6245-02, Session 1

Recent results of integrated sensing and procesing using a programmable hyperspectral imaging sensor

A. Mahalanobis, R. R. Muise, Lockheed Martin Missiles and Fire Control

Abstract not available

6245-03, Session 1

Recent progress of grayscale optical correlator for automatic target recognition

T. Chao, T. T. Lu, H. Zhou, Jet Propulsion Lab.

Abstract not available

6245-04, Session 2

Detection of moving individuals in cluttered scenes

G. Christogiannopoulos, R. C. D. Young, C. R. Chatwin, Univ. of Sussex at Brighton (United Kingdom)

A system is described for the detection of people moving in a video scene, prior to location and following of the major parts of the human body. Objects are detected utilising a background subtraction method which is based on the movements of objects within the scene. The background removal algorithm is designed in a way that allows the background be to constantly up-dated automatically, allowing it to be used over a long period of time. Several methods for improving the outcome from the background removal algorithm are used which include addressing problems caused by variable shading. Mathematical morphology techniques are subsequently employed in order to improve the segmentation achieved in each frame. A pose estimation algorithm is applied in order to detect major body parts and limbs where possible. This is followed by an error correction algorithm to improve the robustness of the technique.

6245-05, Session 2

Target detection in hyperspectral imagery using one-dimensional fringe-adjusted joint transform correlation

M. S. Alam, S. Ochilov, Univ. of South Alabama

A novel one-dimensional (1D) fringe-adjusted joint transform (FJTC) correlation based technique is proposed for detecting very small targets involving only a few pixels in hyperspectral imagery. In this technique, spectral signatures from the unknown hyperspectral imagery are correlated with the reference signature using the 1D-FJTC technique. This technique can detect both single and/or multiple targets in constant time while accommodating the in-plane and out-of-plane distortion. Test results using real life hyperspectral image cube are presented to verify the effectiveness of the proposed technique.

6245-06, Session 2

Embedded predictive controller for optimal operation of wireless heterogeneous sensor networks

A. Talukder, Univ. of Southern California and Jet Propulsion Lab.

In MUSIC (Multi-modality Sensor network for Integrated event detection, Control optimization and resource management), we discuss a mobile distributed sensing platform with novel control optimization algorithms for dynamic adaptation of sensor network operational parameters in response to detected events that allow autonomous monitoring and reporting of dynamic environmental events for extended periods of time. The MUSIC system is designed for a host of applications, such as unmediated data monitoring and record keeping of the environment or health of a patient and handicapped individuals using multiple on-body wearable sensors.

We discuss a novel predictive control methodology for power management in heterogeneous distributed sensor networks that employs an event based control optimization formulation of the resource management problem and discuss a method to adaptively change desired system performance of the sensor network in response to dynamic events. This functionality is critical in field-deployable sensor networks where continuous operation is expensive and system adaptation is critical for extended operation in the face of dynamic external events. Results of our adaptive controller are shown for real medical data and also for synthetic data.

6245-07, Session 3

Automated filter synthesis and training set selection for the MINACE distortion-invariant filter

R. Patnaik, D. P. Casasent, Carnegie Mellon Univ.

Abstract not available

6245-08, Session 3

Position, rotation, scale, and orientation-invariant object tracking from cluttered scenes

P. Bone, R. C. D. Young, C. R. Chatwin, Univ. of Sussex at Brighton (United Kingdom)

A method of tracking objects in video sequences despite any kind of perspective distortion is demonstrated. Moving objects are initially segmented from the scene using a background subtraction method to minimize the search area of the filter. A variation on the Maximum Average Correlation Height (MACH) filter is used to create invariance to orientation while giving high tolerance to background clutter and noise. A log r-θ mapping is employed to give invariance to in-plane rotation and scale by transforming rotation and scale variations of the target object into vertical and horizontal shifts. The MACH filter is trained on the log r-θ map of the target for a range of orientations and applied sequentially over the regions of movement in successive video frames. Areas of movement producing a strong correlation response indicate an in-class target and can then be used to determine the position, in-plane rotation and scale of the target objects in the scene and track it over successive frames.

6245-09, Session 3

Multiframe distortion-tolerant correlation filtering for video sequences

R. A. Kerekes, B. Narayanaswamy, M. J. Beattie, B. Vijaya Kumar, M. Savvides, Carnegie Mellon Univ.

Distortion-tolerant correlation filter methods have been applied to many video-based automatic target recognition (ATR) applications, but in a single-frame architecture. In this paper we introduce an efficient framework for combining information from multiple correlation outputs in a probabilistic way. Our framework is capable of handling scenes with an unknown number of targets at unknown positions. The main algorithm in our framework uses a probabilistic mapping of the correlation outputs and takes advantage of a position-independent target motion model in order to efficiently compute posterior target position probabilities. An important feature of the framework is the ability to incorporate any existing correlation filter design, thus facilitating the construction of a distortion-tolerant multi-frame ATR. In our simulations, we incorporate the MACE-MRH correlation filter design, which allows the user to specify the desired scale response of the filter. We test our algorithm on a database of infrared (IR) video sequences as well as several synthesized sequences, all of which exhibit various degrees of target scale distortion. Our simulation results show that the multi-frame algorithm significantly improves the recognition performance of a MACE-MRH filter while requiring only a marginal increase in computation.

6245-10, Session 3

Fusion of conditionally dependent correlation filter-based classifiers using OR rule for improved biometric verification

K. Venkataramani, B. Vijaya Kumar, Carnegie Mellon Univ.

In practical biometric verification applications, single classifiers may not be very accurate due to large variability in biometric data. In such cases, fusion of multiple classifier outputs through a fusion rule may improve accuracy. Usually, the classifier ensemble is designed in some way without taking into account the fusion rule, and multiple fusion rules are evaluated to find the best fusion rule. In this paper, we approach the inverse problem of designing the best set of classifiers for a given fusion rule. We focus on OR rule fusion for biometric verification here, although the same principle can be extended to other decision fusion rules. Recently, it has been shown that statistical dependence of classifier decisions can improve MAJORITY rule fusion accuracy over statistical independence. In this paper, we theoretically find the favorable as well as unfavorable conditional dependence of classifier decisions for the OR rule. Unlike the MAJORITY rule, the favorable conditional dependence on authentics is different from the favorable conditional dependence on impostors. Based on this information, we design favorable correlation filter based classifiers for the OR rule on the plastic distortion subset of the NIST 24 fingerprint database and the CMU PIE pose and illumination face database. For OR rule fusion, it is favorable to design multiple simple classifiers, one for each distortion present in the database. Preliminary results with 3 classifiers (one for each plastic distortion) per finger on the NIST 24 database and 13 classifiers (one for each pose) per person provides an average EER (Equal Error Rate) of 0.9% for the PIE data and 1.2% for the NIST 24 data on OR rule fusion of these designed classifiers, whereas independent classifiers having the same individual classifier error rates would have a theoretical EER of 26% and 3.2% respectively.

6245-11, Session 3

Improved clutter rejection in automatic target recognition and tracking using eigen-extended maximum average correlation height (EEMACH) filter and polynomial distance classifier correlation filter (PDCCF)

M. F. Islam, M. S. Alam, Univ. of South Alabama

Various correlation based techniques for detection and classification of targets in forward looking infrared (FLIR) imagery have been developed in last two decades. Correlation filters are attractive for automatic target recognition (ATR) because of their distortion tolerance and shift invariance capabilities. The extended maximum average correlation height (EMACH) filter was developed to detect a target with low false alarm rate while providing good distortion tolerance using a trade off parameter (beta). By decomposing the EMACH filter using the eigen-analysis, another generalized filter, called the eigen-EMACH (EEMACH) filter was developed. The EEMACH filter exhibits consistent performance over a wide range which controls the trade-off between distortion tolerance and clutter rejection. In this paper, a new technique is proposed to combine the EEMACH and polynomial distance classifier correlation filter (PDCCF) for detecting and tracking both single and multiple targets in real life FLIR sequences. At first, EEMACH filter was used to select regions of interest (ROI) from input images and then PDCCF is applied to identify targets using thresholds and distance measures. Both the EEMACH and PDCCF filters are trained with different sizes and orientations corresponding to the target to be detected. This method provides improved clutter rejection capability by exploiting the eigen vectors of the desired class. Both single and multiple targets were identified in each frame by independently using EEMACH-PDCCF algorithm to avoid target disappearance problems under complicated scenarios.

6245-12, Session 4

High-speed image search engine using collinear holography

E. Watanabe, K. Kodate, Japan Women's Univ. (Japan)

We have constructed an original optical correlator for fast face recognition called FARCO[E.Watanabe, K.Kodate: Appl.Opt.,44,5,666-676 (2005)]. Its recognition time is limited to 1000frame/s due to the data translation speed and to the storage capacity of the RAM used for storing digital reference images. The recognition rate can still be vastly improved, if reference images are recorded in optical memory and can be accessed directly without transferring them to digital images. In addition, large capacity of optical memory allows us to increase the amount of reference database. Recently, a novel holographic optical storage technology that utilizes collinear holography was demonstrated [H.Horimai,X.Tan, and J. Li : Appl. Opt., 44, 13, 2575-2579 (2005)]. This technology can realize practical, small holographic optical storage systems more easily than conventional off-axis holography. In addition, this volumetric optical disk storage system can be compatible with CD and DVD.

In this paper, we introduce an image search engine that integrates collinear holography and the optical correlation technology used in FARCO. From preliminary correlation experiments using the collinear optical setup, we achieved excellent performance of high correlation peaks and low error rates. We expect optical correlation of 10us/frame provided that 12,000 pages of hologram in one track rotating at 600rpm. That means that it is possible to take correlation of more than 100,000faces/s when applied to face recognition. This system can also be applied to High - Vision image searching.

6245-13, Session 4

Use of shifted phase-encoded joint transform correlation for class-associative color pattern recognition

M. N. Islam, M. S. Alam, Univ. of South Alabama

Color pattern recognition techniques involve the separation of basic color components, red, green and blue, by using color filters. Although several joint transform correlation architectures have been proposed in literature for color pattern recognition, however, these algorithms are suitable for single color target detection only and most of them are sensitive to noise and do not efficiently utilizes the space bandwidth product. A new shifted phase-encoded fringe-adjusted joint transform correlation (SPJTC) technique has been proposed in this paper for class-associative color pattern recognition. The color images are first split into three fundamental color components and the individual components are then processed simultaneously through three different channels. The SPJTC technique for each color component again involves two channels, one with the reference image and the other with 1800 phase-shifted reference image. Both are phase masked using a random phase and then used with the input scene. The joint power spectra (JPS) are again phase masked and subtracted one from the other. The resultant JPS yields the desired correlation after inverse Fourier transformation. A modified class-associative color fringe adjusted filter is developed for providing single and sharp correlation peak per target while satisfying the equal correlation peak criterion for each class member. The salient feature of the proposed scheme is that the number of channels and processing steps remains constant irrespective of the number of members in the class. Computer simulation verifies the effectiveness of the proposed technique for color images both in binary and gray levels even in presence of noise.

6245-14, Session 4

Enhanced rotation and scale-invariant target detection using the fringe-adjusted joint transform correlation

A. M. El-Saba, M. S. Alam, W. Sakla, Univ. of South Alabama

We present a novel discriminant function (SDF) formulated from Laplacian-enhanced (L) training images for the rotation and scale invariant target detection. It is shown that the proposed LSDF yields significantly improved correlation performance parameters compared to the traditional SDF. Since the LSDF is formulated off line it does not has any burden on the processing speed of the system.

6245-15, Session 5

Optical correlator techniques applied to spacecraft docking

D. A. Gregory, The Univ. of Alabama in Huntsville

Established optical correlation techniques will be applied to the problem of pose estimation of spacecraft for autonomous rendezvous and docking. The problem is substantially similar to the recognition and tracking of hostile targets in military applications. The historically deep knowledge base in this area will be exploited for the current investigation so that important discoveries will not have to be reinvented. It is expected that this problem should be somewhat better behaved since the “target” is cooperative and not actively in opposition to being found or recognized. The goal of this investigation is to determine the parameters of interest and to construct somewhat meaningful demonstrations of techniques that could be used for this optical approach to a computationally intense digital problem.

The hardware was built by Boulder Nonlinear in miniature component form based on the traditional 4-f VanderLugt correlator, using kilohertz rate spatial light modulators of their own manufacture. The hardware was then delivered to the US Army Aviation and Missile Research, Development and Engineering Center at Redstone Arsenal, Alabama under a Phase 2 SBIR program. Initial performance measurements of the system indicate that it should be adequate for the application described here.

6245-16, Session 5

A mapping approach for image correction and processing for bidirectional resonant scanners

J. Khoury, C. L. Woods, Air Force Research Lab.; B. Haji-Saeed, S. K. Sengupta, Univ. of Massachusetts/Lowell; J. Kierstead, Solid State Scientific Corp.

Abstract not available

6245-17, Session 5

Optical design automation: a systematic approach for mapping any digital function to linear optics

M. I. Kazantzidis, Broadata Communications, Inc.

High energy physics, climate computations, nanoscience, fusion energy, astrophysics and genomics are applications with high processing and network demands. Optical components can be useful for these application as they can provide ultra fast, high input/output processing and network switching parts. In this paper a core concept is presented that may allow the systematic programming of linear optical components for opto-electronic processors, network switching or have general digital functionality. An optical automated design process is described, under a linear optics model assumption such as can be found in writable or re-writeable holographic material. We use optimization theory and maximum feasibility set (MAX-FS) inspired heuristics to solve the problem of finding optimal performance weights and thresholds for the implementation of a digital or switching function with linear optics. This optical design automation (ODA) may evolve into a rapid prototyping environment for fabless opto-electronics companies to receive custom programming for opto-electronic circuits from system engineers. Using this process, we have successfully designed an 8-bit switch using a single optical stage.

6245-18, Session 5

Three-dimensional wavelet filtering of computer tomography generated images of the liver for texture analysis

B. Ganeshan, R. C. D. Young, K. Miles, C. R. Chatwin, Univ. of Sussex at Brighton (United Kingdom)

Colorectal cancer may have hepatic metastases that are too small to detect with simple visual analysis of Computer Tomography (CT) images. These micrometastases alter hepatic haemodynamics which may produce subtle image features that are revealed by appropriate image processing. Our previous work indicates the potential for computed-assisted diagnosis in identifying, within apparently normal contrast enhanced two-dimensional (2-D) CT images of the liver, textural features at given ranges of spatial scale that reflect hepatic haemodynamics and identifies colorectal cancer patients with reduced survival. In this paper, we report the development of a three-dimensional (3-D) texture analysis technique to assess whole liver, rather than single 2-D slices, as texture anisototropy in a 3-D volume may improve our preliminary results in identifying colorectal cancer patients.

A three dimensional (3-D) CT liver volume dataset of a patient with colorectal cancer was employed, each slice containing 512 x 512 pixels with pixel dimensions of 0.84 mm x 0.84 mm and slice reconstruction at a 2 mm interval. The 2-D slices were down-sampled to obtain a pixel width of 2mm x 2mm, thus resulting in a cubic voxel of dimension of 2 x 2 x 2 mm3. A 3-D Laplacian of Gaussian filter mask was generated for different pass-band regions in order to highlight fine to coarse texture within the

volume. 3-D Fourier transformations of the liver volume and filter mask were obtained and their product computed. The filtered volume in the spatial domain was obtained by taking the inverse 3-D Fourier transform of this product. This 3D filtered volume highlighted textural features within different bands of spatial frequencies.

The 3-D texture of the liver was viewed using maximal intensity projection. We quantify the texture over different spatial scale ranges to initially assess whether 3-D texture analysis has the potential to improve our 2-D results in identifying colorectal cancer patients.

6245-19, Session 6

A high-resolution and high-speed 3D imaging system and its application on ATR

T. T. Lu, T. Chao, Jet Propulsion Lab.

Abstract not available

6245-20, Session 6

Efficient image preprocessing for topological or syntatical pattern recognition

C. J. Hu, Southern Illinois Univ. Carbondale

As we published last year, we have developed a very efficient image preprocessing scheme for using in any image analyzing system or any pattern recognition system. This scheme will analyze an edge-detected binary image and break it down to many “simple” branches by the automatic line tracking method we published earlier. Each branch can then be curve-fitted with the standard Window functions and it will result in an analog output which contains the starting point and the ending point xy-coordinates, the polynomial degree and coefficients in the best-fit algebra expression, and the angle of rotation to make the polynomial fitting work. The original binary image then can be closely reconstructed with this compact analog data. The reconstructed image is seen to be highly accurate compared to the original image in all our experiments.

This paper reports the description of the topological structure of the original binary image detected by this novel image pre-processing method. That is, it will tell us how many branching points, how many single-ended points will be detected, and what algebraic curves are connected among them. This “topological” description of the image is not only very specific, but also very robust because when the image is viewed in different elevations and different directions, even though the geometrical shape changes, the topological or syntactical description will NOT change. Therefore it can be used in very fast learning, and very robust, yet very accurate, real-time recognition.

6245-21, Poster Session

Pattern recognition correlator based on digital photo camera

S. N. Starikov, N. N. Balan, V. G. Rodin, I. V. Solyakin, E. A. Shapkarina, Moscow Engineering Physics Institute (Russia)

Diffraction image correlator based on commercial digital SLR photo camera is described. The correlator is proposed for recognition of external 2-D and 3-D scenes illuminated by quasimonochromatic spatially incoherent light. Principal optical scheme of the correlator is analogous to that of incoherent holographic correlator by Lohmann. The correlator hardware consists of digital camera with attached optical correlation filter unit and control computer. No modifications have been introduced in units of commercial digital SLR photo camera. Digital camera was connected via camera interface to computer for controlled camera shooting, transfer of detected correlation signals and post-processing. Two ways were used for correlation filter unit mounting. In the first case, correlation filter was attached to the front of the camera lens. In the second one, it was placed in a free space of the SLR camera body between the interchangeable camera lens and the swing mirror. Computer generated Fourier holograms and kinoforms were used as correlation filters in experiments. The experimental setup of the correlator and experimental results on images recognition are presented. The recognition of test objects of direct and reversed contrast with the same correlation filter was performed.

6245-22, Poster Session

Confuser rejection performance of EMACH filters for MSTAR ATR

D. P. Casasent, A. Nehemiah, Carnegie Mellon Univ.

A synthetic aperture radar (SAR) automatic target recognition (ATR) based on the extended maximum average correlation height (EMACH) distortion invariant filter (DIF) is presented. Prior work on the EMACH filter addresses 3-class and 10 class classification with clutter rejection. However, the ability of the EMACH filter to reject confusers is not well known. We follow a benchmark procedure which involves classification of three object classes and rejection of two confusers from the Moving and Stationary Target Acquisition and Recognition (MSTAR) public database. This is a hard problem since MSTAR images are specular and has a full 360 degree aspect angle range. In addition, the classification scheme should be able to handle object variants and depression angle differences between training and test sets, and the classification scheme should also be able to discriminate against other unseen objects (confusers). A set of EMACH filters covering different aspect angle ranges is synthesized for each object class using training set images of that object class and a validation set of images of that object class and clutter images. We also present a scheme to select which training set images to include while making the filters, since it is not necessary to use all training set images to make the filters. Results for classification with both confuser and clutter rejection are presented. We also compare our work with prior EMACH MSTAR work.

6245-23, Poster Session

Performance of non-identical cameras for facial biometrics systems

A. C. Lin, C. L. Woods, Air Force Research Lab.

Facial verification and recognition techniques normally require the same imaging system for the acquisition of both template and test images for the recognition software to perform accurately, according to previous studies. In fields such as law enforcement where it is common for different agencies to use different equipment, this incompatibility between systems that use the same biometric may pose a serious limitation. In another area of concern, imaging systems may become discontinued making replacement impossible and legacy data obsolete. In this study, we evaluate the False Acceptance Rate (FAR) and False Rejection Rate (FRR) performance of a digitally simulated optical correlator using Binary Phase-Only Filters (BPOF) and Phase-Only Filters (POF), on images acquired across non-identical cameras for a cooperative building-entry security system with a fixed illumination environment. This work is supported by Air Force Office of Scientific Research (AFOSR).

6245-25, Poster Session

Land-cover mapping from remote sensing data

C. J. Wong, Univ. Sains Malaysia (Malaysia)

Remote sensing data have been widely used for land cover mapping using supervised and unsupervised methods. The produced land cover maps are useful for various applications. This paper examines the use of remote sensing data for land cover mapping over Saudi Arabia. Three supervised classification techniques Maximum Likelihood, ML, Minimum Distance-to-Mean, MDM, and Parallelepiped, P were applied to the imageries to extract the thematic information from the acquired scene by using PCI Geomatica software. Training sites were selected within each scene. This study shows that the ML classifier was the best classifier and produced superior results and achieved a high degree of accuracy. The

preliminary analysis gave promising results of land cover mapping over Saudi Arabia by using Landsat TM imageries.

6245-27, Poster Session

The systems for persons' identification and verification on the basis of face correlation recognition

V. L. Perju, Technical Univ. of Moldova (Moldova); A. Galben, Free Independent Univ of Moldova (Moldova)

In terrorism and organized crime combating one of the important problems becomes the identification and verification of persons. In the article is presented a PC based system for persons' identification and verification on the bases of faces correlation recognition. There are described the structure and the realized functions, the software, the interfaces, the options of image processing. The elaborated system permits to introduce images of different resolution using sensors as TV camera, Web camera, digital camera or scanner. The system permits to create the data base, personal records, the realization of searching operations. There are presented the investigation results of influences the noise, rotation and scale of the images on the identification results. The data shows that the noise with the probability p=0.1, the rotation with the angle 1 degree and the scale with 2% of the input images leads to the correlation function maximum's decrease with 60%. Due to this fact for faces recognition it was proposed to use the correlation method based on the image presentation in the polar system of coordinates. The experiments showed the stability in faces recognition at rotation and scale changes of the images in this case. At the same time it is necessary to use the noise removal operations. There are presented the data concerning the recognition time for the images of different resolution and for the processors with different frequency. In order to increase the system's productiveness it is elaborated an optical-electronic system.

6245-29, Poster Session

Non-conventional joint transform correlation using grating filters and heterodyne scanning techniques for pattern recognition applications

A. K. Cherri, Kuwait Univ. (Kuwait); M. S. Alam, Univ. of South Alabama

Two non-conventional real-time joint-transform correlation (JTC) architectures are presented where spatial light modulators (SLM) are not required at the Fourier planes. In the first one, simple grating filters such as rectangular, triangular, or sinusoidal ones are used along with a heterodyning one-dimensional scanning technique to capture the cross-correlation function of the input images, which significantly reduces the processing time needed for real-time applications while eliminating the drawbacks associated with non-ideal characteristics of the SLMs. Note that the processing time of the proposed system depends on the speed of the optical scanner which performs the one-dimensional scanning. To enhance processing speed, acousto-optical scanners can also be used.

In the second architecture, we propose a faster technique using two grating filters such that the proposed system does not depend on the how fast the optical scanner performs the one-dimensional scanning.

Detailed analytical modeling for the proposed JTC architectures has been developed. The performance of the proposed methods has been evaluated using both undistorted and distorted (rotation, scaling, noise) images via simulation experiments.

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6246-02, Session 1

A comparison of visual statistics for the image enhancement of FORESITE aerial images with those of major image classes

D. J. Jobson, NASA Langley Research Ctr.; Z. Rahman, College of William & Mary; G. A. Woodell, G. D. Hines, NASA Langley Research Ctr.

Aerial images from FORESITE flight tests of a research Boeing 757 were acquired during severe haze and haze/mixed clouds visibility conditions. These images were enhanced using the Visual Servo (VS) process that makes use of the Multiscale Retinex. The images were then quantified with visual quality metrics used internally within the VS. One of these metrics, the Visual Contrast Measure, has been computed for hundreds of FORESITE images, and for major classes of imaging - terrestrial (consumer), orbital earth observations, orbital Mars surface imaging, and underwater imaging. The metric quantifies both the degree of visual impairment of the original, un-enhanced images as well as the degree of visibility improvement achieved by the enhancement process. The large aggregate data exhibits trends relating to degree of atmospheric visibility attenuation, and its impact on the limits of enhancement performance for the various image classes. Overall results support the idea that in most cases that do not involve extreme reduction in visibility, large gains in visual contrast are routinely achieved. Additionally, for very poor visibility imaging, lesser, but still substantial gains, in visual contrast are also routinely achieved. Further, the data suggest that these visual quality metrics can have uses other than as external standalone metrics for establishing performance parameters.

6246-03, Session 1

Novel method of tensor representation for reconstruction of 3D PET images from projections

S. Alla, A. M. Grigoryan, J. M. Moreno, The Univ. of Texas at San Antonio

In this paper, a novel transform-based method of reconstruction of three-dimensional (3-D) Positron Emission Tomography (PET) images is proposed. Most of analytical reconstruction algorithms attempt to adapt Radon's fundamental theory to the discrete model. As a result of this, the results of such algorithms are erroneous. The proposed method is based on the concept of non-traditional tensor and paired forms of representation of the 3-D image with respect to the 3-D discrete Fourier transform (DFT). Such representations require a minimal number of projections to be derived. The proposed algorithms are described in detail for an image (NxNxN), where N is a power of two. The paired transform is not the Radon transform, but the unitary transform completely defined by projections along the discrete grid nested on the image domain. The measurement data set containing specified projections of the 3-D image are generated according to the paired representation and the proposed algorithm is tested on the data. The algorithm for selecting a required number of projections is described. This algorithm allows the user to select the projections that contain the maximum information and automatically selects the rest of projections, so that there is no redundancy in the spectral information of the projections. The efficiency of the algorithm is expressed in the fact that it requires very minimal number of multiplications, or could be implemented without such at all. The data is reconstructed using 3-D FBP and the results are compared to the conventional algorithms.

6246-04, Session 1

Processing of visual information in the visual and object buffers of scene understanding system based on network-symbolic models

G. Kuvich, Smart Computer Vision Systems

Modern computer vision systems suffer from the lack of human-like abilities to understand visual scene and detect and unambiguously identify and recognize objects. Bottom-up fine-scale segmentation of image with the following grouping into regions can rarely be effective for real world images if applied to the whole image without having clear criteria of how further to combine obtained small distinctive neighbor regions into meaningful objects. Just on a certain scale, an object or a pattern can be perceived as an object or a pattern rather than a set of neighboring regions. Therefore, a region of interest, where the object or pattern can be located, must be established first. Rough but wide peripheral human vision serves to this goal, while narrow but precise foveal vision analyzes and recognizes object that can be found in the center of the region of interest after separating the object from its background. Visual intelligence provides scene and object contexts, and resolves ambiguity and uncertainty in the visual information. Perceptual grouping is one of the most important processes in human vision, and it binds visual information into meaningful patterns and structures. Unlike the traditional computer vision models, biologically-inspired Network-Symbolic models convert image information into an "understandable" Network-Symbolic format, which is similar to relational knowledge models. The equivalent of interaction between peripheral and foveal systems in the network-symbolic system is achieved via interaction between Visual and Object Buffers and top-level knowledge system. This article describes data representation and information processing in Visual and Object buffers required for scene analysis and understanding with identification and recognition of objects in the visual scene.

6246-05, Session 1

Multiscale self-similarity features of terrain surface

X. Li, H. Cao, G. Zhu, S. Yi, Huazhong Univ. of Science and Technology (China)

Self-similarity features of natural surface play a key role in region segmentation and recognition. Self-similarity is the most important character of fractal. From the theoretical viewpoint, a surface is a perfect self-similar set, and then the self-similarity parameter (for example, fractal dimension and Hurst parameter, etc.) remains constant over all ranges of scales. However, each terrain surface is composed of many self-similar structures; the Self-similarity is not always so perfect that remains invariable in whole scale space. The traditional single self-similarity parameter can not stand for such abundant self-similarity. In order to describe real surface, we adopt the Fractional Brownian Motion (FBM) model to estimate the self-similarity curve of terrain surface. And then, the curve is divided into several linear regions to describe such abundant self-similarity. Based on the division of the linear regions, we introduce a parameter called Self-similar Degree in the similitude of information entropy. The small value of Self-similar Degree indicates the more consistent Self-similarity. Furthermore, the Hurst parameter is not a constant over all scales in this paper, but a diversified parameter according to certain scale region. Therefore the similarity feature sets could be made up of these Hurst parameters and Self-similar Degree to a real terrain surface. We adopt several different terrain images to study their self-similarity characters. For each object, we evaluate the Self-similar Degree and Hurst parameters of the scale regions. The experiment results indicate the distances of different

model feature are always greater than monotone fractal feature. Hereby, the multi-scale self-similarity features sets provide crucial information in terrain recognition and segmentation.

6246-06, Session 2

User evaluation of differential compression for motion imagery

L. D. Gibson, J. M. Irvine, G. O'Brien, S. R. Schroeder, A. P. Bozell, S. A. Israel, L. R. Jaeger, Science Applications International Corp.

Motion imagery will play a critical role in future combat operations. The ability to provide a real time, dynamic view of the battlefield and persistent surveillance make motion imagery a valuable source of information for the soldier. Acquisition and exploitation of this rich source of information, however, will depend on available communication channels to transmit the necessary information to users. Methods for reducing bandwidth requirements include image compression and frame decimation. This paper describes a study undertaken to explore spatially differential compression in which targets in the clips are losslessly compressed, while the background regions are highly compressed. The study evaluated the ability of users to perform standard target detection and identification tasks on the compressed product, compared to performance on uncompressed imagery or imagery compressed by other methods. The paper concludes with recommendations for future investigations.

6246-07, Session 2

Automatic network-adaptive ultra-low bit-rate video coding

W. Chien, T. Lam, Arizona State Univ.; G. P. Abousleman, General Dynamics C4 Systems; L. J. Karam, Arizona State Univ.

This paper presents a software-only, real-time video coder/decoder (codec) for use with low-bandwidth channels where the bandwidth is unknown or varies with time. The codec incorporates a modified JPEG2000 core and interframe predictive coding, and can operate with network bandwidths of less than 2 kbits/second. The encoder and decoder establish two virtual connections over a single IP-based communications link. The first connection is UDP-IP guaranteed throughput, which is used to transmit the compressed video stream in real time, while the second is TCP-IP guaranteed delivery, which is used for two-way control and compression parameter updating. The TCP-IP link serves as a virtual feedback channel and enables the decoder to instruct the encoder to throttle back the transmission bit rate in response to the measured packet loss ratio. It also enables either side to initiate on-the-fly parameter updates such as bit rate, frame rate, frame size, and correlation parameter, among others. The codec also incorporates frame-rate throttling whereby the number of frames decoded is adjusted based upon the available processing resources. Thus, the proposed codec is capable of automatically adjusting the transmission bit rate and decoding frame rate to adapt to any network scenario. Video coding results for a variety of network bandwidths and configurations are presented to illustrate the vast capabilities of the proposed video coding system.

6246-08, Session 2

Human face detection in video using dynamic programming

A. E. Cetin, M. Turkan, Bilkent Univ. (Turkey)

A face can be recognized by its edges. In fact, a caricaturist draws a face image in a few strokes by drawing the major edges of the face. Most wavelet domain image classification methods are also based on this fact because wavelet coefficients are closely related with edges, see e.g., [Garcia 1999].

The first step of the algorithm is to find possible face regions in a typical image or video. This can be determined by detecting regions with possible human skin colors. In these regions edges are estimated by using a standard edge detector. Edges can be estimated by summing the absolute values of high-low, low-high and high-high wavelet sub-images of the two-dimensional wavelet transform as well. Wavelet coefficients of the low-high (high-low) sub-image correspond to horizontal (vertical) edges of the image region.

After computing the edges in skin coloured region, their horizontal and vertical projections are computed. The horizontal (vertical) projection is simply computed by summing the pixel values in a row (column) in the edge image. One can also obtain similar plots from frontal face drawings or caricatures. Horizontal and vertical edge projections are good features to represent a face image because they are robust to pose angle. Another advantage of the projections is that they can be normalized to a fixed size and this provides robustness against scale changes.

Horizontal and vertical edge projections are used as features in pattern classification which can be carried out using dynamic programming or a standard neural network or support vector machines. Dynamic Programming was used in finite vocabulary speech recognition and various communication theory applications (e.g., the Viterbi algorithm) but it is not widely used in pattern analysis and image processing. The main reason that we want to use dynamic programming is that it produces better results than neural networks and HMM in small vocabulary speech recognition.

The dynamic programming is used to compare the projection plots of a region with typical face templates. Three template couples corresponding to frontal, 45 and 90 degrees are used in the current face recognition system.

The recognition performance of the dynamic programming will be compared to neural networks and support vector machines. Also, the proposed face detection method using dynamic programming will be compared to the currently available face detection methods in the final form of the paper.

6246-10, Session 3

Superresolution restoration based on motion estimation error and edge-adaptive constraints

M. Liu, H. Cao, S. Yi, X. Li, Huazhong Univ. of Science and Technology (China)

Super-resolution restoration is extensively studied in recent years, it is widely used in remote sensing, frame freeze in video, military surveillance and medical diagnostics. Both in spatial and compress domains, the POCS algorithm of sets theory is effective and extensible. In conventional POCS algorithm, it is assumed that the motion estimation error is neglected or considered the same for all low-resolution images, however, from statistical result, the standard deviation of motion estimation error is proportional to the distance between two frames. On the other hand, ringing artifact always exists along object's edges due to overestimation of degradation parameter since all the pixels are treated identically. In order to overcome the two drawbacks, we propose an algorithm based on POCS combining with motion estimation error analysis and edge restriction. In this approach, the standard deviation of the motion estimation error is calculated in each projection step, so the threshold value for projection restoration is determined by it adaptively. Furthermore, to reduce the ringing artifact, edge constraint is adopted, the pixels on edges are located, and then the standard deviations of pixels along different directions are compared. We find the smallest one that stands for the pixel's direction, along which the pixel should be repaired. It is noticeable that all these are feasible without increasing much calculation burden. Experimental results indicate that the proposed algorithm outperforms linear interpolation and conventional approach in terms of both objective measurements and visual evaluation.

6246-11, Session 3

Past success and future challenges in computational imaging

E. R. Dowski, Jr., CDM Optics, Inc.

Computational Imaging has undergone many changes in the last few years. In a very short time the technology behind computational imaging has experienced a large evolutionary change. Only a few years ago computational imaging was often considered impossible; now it is often considered essential. These changes have been due to a number of important factors and supporting technologies. Anticipating future technology needs leads to important challenges and directions for both commercial application and university research.

One significant reason for the past success of computational imaging is the software tools for simulation and design that CDM Optics has been developing over the past years. These tools have allowed the practical simulation, design, and optimization of computational imaging systems. Management of system complexity through quality tools has also allowed the design of systems whose overall system complexity greatly exceeds that of other earlier imaging systems.

A major future challenge in computational imaging centers on verifiable and broadly understandable methods of describing “image quality”. For some task-based systems, image quality can be easily defined through compact numeric measures such as probability of detection vs false alarm. As the vast majority of computational imaging systems in the foreseeable future will be viewed by humans, effective human-viewed metric need to be determined. And, as the design of computational imaging systems is essentially a large scale trade-off exercise, the understanding and dissemination of human-viewed image quality will soon become critical to future development.

6246-12, Session 3

Compressive imaging spectrometers using coded apertures

D. J. Brady, M. E. Gehm, Duke Univ.

Coded apertures enable efficient sampling in compact low-cost optical systems for hyperspectral imaging. Coded aperture spectrometers may be designed to reproduce the spectral data cube without the “missing cone” associated with computed tomographic spectral imagers and with much higher optical throughput that tunable filter based imagers. Well-conditioned spectral imaging is based in part on the capacity of aperture coding to induce a shift variant impulse response. Shift variant, noncovex and multiscale impulse responses also enable compressive sampling in spectral imaging systems.

6246-13, Session 3

New high-dynamic-range camera architecture

A. Cernasov, Honeywell Defense and Space Electronic Systems

The need for wide dynamic range cameras in the Security and Defense sectors is self-evident. Still the development of a cost-effective and viable system proves to be more elusive than expected. In this pursuit the author takes a new approach which meets a number of requirements, most notably a high “fill” factor for the associated APS array and a minimum technology development curve. The approach can be used with any sensor array supporting, on the granular level, random pixel access. To achieve a high dynamic range the presented camera system classifies image pixels according to their probable output levels. Then it scans the pixels according to their predicted brightness, with the pixels most likely to be the brightest being scanned first and the pixels most likely to be the darkest, last. Periodically the system re-adjusts the scanning strategy based on collected data or operator inputs. The overall exposure time is dictated by the sensitivity of the selected array and the scene illumination conditions. The local exposure time is determined by the predicted local brightness level. The paper will include at least one strategy of predicting “a priori” the brightness of the image pixels. This approach was found to require only minimal modifications to standard active pixel array architectures and less “off-sensor” resources than CAMs or other DSP intensive approaches. This further results in lower power consumption, a critical factor in portable, remote, and airborne applications.

6246-14, Session 4

Adaptive image processing for low radiation x-ray inspection

S. M. Sheraizin, VLSCOM LTD. (Israel)

Modern image processing technology based on the adaptive Wiener, Karhunen-Loeve, wavelet , block-threshold etc. filtering can improve spatial resolution and the contrast of low radiation x-ray pictures. As is well-known, the improvement range is small enough because the denoising results in the spatial resolution lowering and both contrast and spatial resolution enhancement gains a noise level.

We have developed a new method of low radiation X-ray picture quality enhancement. The method is based on our set-theoretical model of the video data. For human visual picture analysis the video data model can be described by the metric space mn , where the metric (distance) is determined as the maximum luminance levels difference between two details.

Based on the video data metric space the details can be clustered on a class of large details (dimensions are 4 times more than a X-ray systems spatial resolution) and a low dimension class that is divided into two subclasses of distinguishable details and detectable details. The last details are characterized with the signal-to-noise ratio SNR lower than 3 to 5.

Both the video data model and graininess model (noise affected all spatial frequency range) are used for developing an effective radiographic picture processing adaptive to picture content. The contrast improvement is based on separated nonlinear processing both large and distinguishable small details providing a gray scale stretch. Detectable details and the noise components are processed by a polynomial transformer like the human visual system detects low contrast small details. The adaptive processing provides a contrast improvement without noise visibility increase.

Spatial resolution enhancement is based also on the separated processing of distinguishable and detectable small details and edges. The processing is adaptive to local picture contrast and the small details contrast. The detectable small details processing uses an adaptive matched filter providing the maximum probability of a detail detection(maximum SNR).

The developed processing was carefully checked by using various specific phantoms(X-ray test patterns) with radiation dose variation from normal to half(50%) dose. In most cases the half dose processed pictures provide the same picture quality and picture analysis (inspection) results as for full dose pictures.

6246-15, Session 4

Quantitative confirmation of visual improvements to micro-CT bone density images

J. S. DaPonte, M. Clark, T. J. Sadowski, E. Wood, Southern Connecticut State Univ.

The primary goal of this research was to investigate the ability of quantitative variables to confirm qualitative improvements of an iterative deconvolution algorithm as a preprocessing step in evaluating micro CT bone density images. The analysis of these images is important because they are necessary to evaluate various countermeasures used to reduce or potentially reverse bone loss experienced by some astronauts when exposed to extended weightlessness during space travel. Nine low resolution (17.5 microns) CT bone density image sequences were processed with three preprocessing treatment groups consisting of no preprocessing, preprocessing with a deconvolution algorithm and preprocessing with

a Gaussian filter. The quantitative parameters investigated consisted of Bone Volume to Total Volume Ratio, the Structured Model Index, Fractal Dimension, Bone Area Ratio, Bone Thickness Ratio, Euler's Number and the Measure of Enhancement. The trends found in these quantitative features seem to corroborate our previous findings that a deconvolution algorithm is superior for preprocessing micro CT bone density images when compared to a Gaussian filter.

6246-16, Session 4

Advanced image processing of aerial imagery

G. A. Woodell, D. J. Jobson, NASA Langley Research Ctr.; Z. Rahman, College of William & Mary; G. D. Hines, NASA Langley Research Ctr.

Aerial imagery of the Earth is an invaluable tool for the assessment of ground features, especially during times of disaster. Researchers at NASA's Langley Research Center have developed techniques which have proven to be useful for such imagery. Aerial imagery from various sources, including Langley's Boeing 757 Aries aircraft, has been studied extensively. This paper discusses these studies and demonstrates that better-than-observer imagery can be obtained even when visibility is severely compromised. A real-time, multi-spectral experimental system will be described and numerous examples will be shown.

6246-17, Session 4

Improved stego-sensitivity measure for +/-A steganalysis

S. S. Agaian, The Univ. of Texas at San Antonio; B. M. Rodriguez II, Air Force Institute of Technology

Steganography is the hiding of a message within another message so that the presence of the hidden message is indiscernible. This article presents an improved version of Stego Sensitivity Measure which was used for the detection of steganographic content. The message length is calculated using the number of suspected stego pixels. It based on the statistics of sample pair and is very sensitive to +/-A embedding. The essential goals of this article are:

1.To enhance the evaluation of the stego evidence within images.

2.To calculate the message length of the embedded data.

3.To identify the "steganographic fingerprint" of spatial domain based steganographic methods.

4.To comprehensively study pixel comparison based steganalysis methods.

This method, for the case of +/-1 embedding (A = 1), was compared with commonly used LSB steganalysis methods: such as RPQ, RS Steganalysis and commercially available steganalysis software. Computer simulation of 300 test images have shown that a) it improves the stego detection accurateness over other methods when adaptive embedding method is used; b) It enhances stego detection and localization accuracy of stego areas within color or gray images when compared with Stego Sensitivity Measure; c) the detection and separation of stego information within transitional pixels, i.e., changes of texture within images. In addition, it demonstrates good detection performance in measuring the detection message length. The method also demonstrates the average detection error is 0.02 when analyzing 8 by 8 blocks for 300 test images containing 0, 2.5, 5, 7.5, 10 and 15 percent strgo.

6246-18, Session 5

Evaluation of sharpness measures and search algorithms for the auto-focus of high-magnification images

Y. Yao, B. R. Abidi, The Univ. of Tennessee; N. Doggaz, Univ. de Tunis (Tunisia); M. A. Abidi, The Univ. of Tennessee

Digital imaging applications with extreme zoom capabilities are traditionally found in astronomy and wild life monitoring. More recently, the need for such capabilities has extended to wide area surveillance and monitoring such as forest fires, airport perimeters, harbors, and waterways. Image based passive auto-focusing techniques are of increased interest primarily because no additional equipment, such as range finding sensors and split prism devices, is required.

In general, auto-focusing is achieved by evaluating the sharpness of collected images and searching for the focus position that produces the best image sharpness. In addition to some well known sharpness measures, such as the Tenengrad and Laplacian [1], edge-based sharpness measures [2-4], have emerged in recent years. This paper looks into various sharpness measures published to date and compares their performances with focus on the evaluation of high magnification images (magnification \> 100x). Such images suffer from substantial blurriness caused by major degradations due to air turbulences and empty magnifications.

This paper also reviews existing search algorithms for best focus position, such as the optimal search strategy, Fibonacci search [1], and the more recently developed rule based search [5], a variable step size algorithm. The performance of each search method in conjunction with the various sharpness measures are examined in these aspects: accuracy, computational complexity (number of iterations and total motor steps traveled), and stability (the robustness to image noise and sensitivity to algorithm parameter selection). In addition, their applicability to high magnification systems and their adaptability to a wide range of magnifications (100x~1000x) are addressed. This study builds up the foundation for the development of auto-focusing schemes with particular application to high magnification systems.

6246-19, Session 5

A system for behavior analysis and threat detection

W. Badawy, Smart Camera Technologies (Canada)

This paper presents a multi-camera system for behavior analysis and thread detection. The system recognizes the dynamics of the object, it maps into rules and detect threat potential. The system detects and classifies objects based on their behaviors. The system also generates alarms for un-authorized and mal-behaved targets. The paper will present the result of a pilot to measure the efficiency in out door application with sever weather condition of deploying this system over water channels.

6246-20, Session 5

Value mapping for gradient-based colorization of two-dimensional fields

A. Visvanathan, S. E. Reichenbach, Univ. of Nebraska/Lincoln

This paper develops a method for colorizing images of two-dimensional fields in order to highlight local changes in values. In many applications, local changes in values may be as important as magnitudes of values. For example, to visually identify steep slopes in low-lying regions from a grid of elevation values requires colorization based on both gradient (for slope) and value (for elevation). The method presented here yields a function that maps pixel values from the input image to a one-dimensional color scale in a way that accounts for gradients in the image. The value mapping function is monotonically increasing, to maintain value relationships on the color scale, and the color scale is used to index into a grayscale or pseudo-color scale to highlight local changes in values. The method first computes the gradient at each pixel. Then, the pixels (with associated gradient) are normalized and sorted by value. The value mapping function is computed from the array of sorted pixel values: the input is the normalized pixel value and the output is the normalized cumulative-gradient. The value mapping uses the color scale at each value in proportion to the gradients observed at pixels with that value. The value mapping method is demonstrated with data from comprehensive two-dimensional gas chromatography (GCxGC) using both grayscale and pseudocolor scales. The colorization highlights local changes related to both small and large peaks in the GCxGC data.

6246-21, Session 5

Automated onboard terrain analysis for precision landings

Z. Rahman, College of William & Mary; D. J. Jobson, G. A. Woodell, G. D. Hines, NASA Langley Research Ctr.

Advances in space robotics technology hinge to a large extent upon the development and deployment of sophisticated new vision-based methods for automated in-space mission operations and scientific survey. To this end, we have developed a new concept for automated terrain analysis that is based upon a generic image enhancement platform-Retinex/visual servo processing. This pre-conditioning produces a "canonical" visual representation that is largely independent of lighting variations, and exposure errors. Enhanced imagery is then processed with a biologically inspired two-channel edge detection process. With this adaptive edge detection process output, terrain classification is automatically performed both at the local and global scales-to define "rugged", "rolling", and "smooth" terrains. In this way, mission and scientific analysis by human specialists is significantly improved by allowing much analysis to be done onboard. Only potentially suitable image data need be reviewed by the human specialists for verification purposes or higher-level study. Further, landing ellipses for future missions can be automatically superimposed on potential landing sites selections to provide a more detailed estimation of landing site suitability. Finally, the terrain analysis can become an integral part of future partially or fully-automated landing subsystems. Augmented by such ancillary data as astronaut visual assessment and/or range/tracking information from guidance and navigation sub-systems, the proposed terrain analysis (if implemented in real-time hardware) can add the capability to rapidly determine the "smoothest" terrain in the forward looking path of a landing approach, and produce guidance signals to steer toward it, and, as well, produce "alarm" signals if high-relief topography appears in a projected landing approach path.

6246-22, Session 5

Paired directional transform-based methods of image enhancement

F. T. Arslan, J. M. Moreno, A. M. Grigoryan, The Univ. of Texas at San Antonio

An effective realization of the a-rooting method of image enhancement by splitting-signals is proposed. The splitting-signals completely determine the image and split its spectrum by disjoint subsets of frequencies. Such splitting is referred as the paired representation and is considered with respect to the Fourier transform. Image enhancement is reduced to processing separate splitting-signals. We focus on processing only one specified splitting-signal, to achieve effective image enhancement that in many cases exceeds the enhancement by known a-rooting and wavelet methods. An effective realization of enhancement of image (NxN) is achieved by using one coefficient, instead of N/2 such coefficients for splitting-signals in the split a-rooting and NxN in traditional a-rooting. The proposed method does not require Fourier transforms, its realization is performed with N multiplications. The processing of the splitting-signal leads to the change of the image along the parallel lines by N different values, which leads to the concept of directional images and their application in enhancing the image along directions. Splitting-signals can be used in underwater oceanographic studies. Arial images are corrupted by clutters caused by surface water waves. Clutters are directional and can be detected and denoised by the paired representation. A novel method of combining paired transform (pre-step of SMEME filter) by wavelet transforms is proposed. While denoising directional clutters, the most corrupted splitting-signal is estimated and found, depending on the angle of long-waves. Advantages of using splitting-signals are in the fact that they can be estimated in accordance with the direction of clutter, which does not require image rotation, neither interpolation.

6246-23, Session 5

VQ-based robust image watermarking

D. Charalampidis, Univ. of New Orleans

A robust watermarking method based on vector quantization (VQ) is proposed as an improvement to existing VQ watermarking techniques. Image watermarking is important for copyright protection, and content authentication. Robust watermarks are used for copyright protection because they are resistant to most common image processing operations. The proposed technique improves existing VQ robust watermarking techniques by investigating the image characteristics and codeword index assignments. Experimental results illustrate that the proposed method exhibits superior performance compared to existing techniques for a variety of attacks.

6246-24, Session 5

Animating climate model data

J. S. DaPonte, T. J. Sadowski, P. Thomas, Southern Connecticut State Univ.

Understanding variability of climate in the West African Sahel region is important because of serious potential socio-economic impact of periodic droughts. Of particular interest is the ability to better predict summer monsoons needed for future regional planning. Analyzing data generated by mathematical models has an increased level of significance because there are few meteorological stations in West Africa. The primary goal of this paper is to demonstrate how animations of this type of data can be used to help better understand climate variability. Climate data for West Africa from June to September 2002 on 0.5 ° latitude by longitude grid was processed with Matlab and NIH IamgeJ to produce animated GIF and AVI files. Animations are an ideal way to analyze scientific data sets of this nature since they have a temporal aspect with each frame representing a single time period. Both precipitation and circulation data have been analyzed in an attempt to provide improved insight into this region's climate dynamics. The precipitation data consists of a single rainfall value for each grid point while the circulation data consists of vector fields with horizontal and vertical wind velocity components. While attempts have been made in the past to simplify the visualization of climate data using vector fields and streamlines to capture flow patterns, to the best of our knowledge no attempts have been made to animate this type of data in the past.

6246-25, Session 5

A system for tracking and recognizing pedestrian faces using a network of loosely coupled cameras

L. Gagnon, F. Laliberté, CRIM (Canada); D. Laurendeau, Univ. Laval (Canada)

We report about the development of a module that is able to characterize pedestrians face during monitoring of extended premises by a network of loosely coupled cameras. The system automatically (1) recognizes facial expressions of pedestrians and (2) builds and store a model of the pedestrian face that can be compared to other face models in order to determine if the person has already been seen or not. Faces are first detected in the video sequence prior to facial feature extraction for face normalization. Gabor filters responses at different scales and orientations are then sampled on a regular grid covering the face to build a facial feature vector. The resulting vectors are normalized and reduced in dimensions before being fed to a classifier of six basic emotions and the neutral state: anger, disgust, fear, happiness, sadness, and surprise. The pedestrian's face model is built while he is within the camera field of view. The model is stored and made available for comparison to other face models with or without taking into account the recognized expressions.

Our face characterization module has been developed as part of a larger video surveillance project, called MONNET (Monitoring of extended pre-

mises: tracking pedestrians using a network of loosely coupled cameras), which aims at the development of a system prototype for the monitoring of public premises using a network of loosely coupled cameras. MONNET is a multi-node video surveillance system. Each node is composed of infrared and optical cameras, as well as a processor unit made of four interacting modules for acquisition, segmentation, tracking, and person identification. The nodes do not necessarily have overlapping field of view and the system does not have a central information server. Rather, each node processes the collected information (in almost real-time) and exchanges it with the other nodes. The information about the person identification module is a high-level model of each pedestrian seen at each node (no image is transferred between nodes). A pedestrian model is composed of face characterization, clothes color and texture, as well as gait description.

6246-26, Poster Session

Moving traffic object retrieval in H.264/AVC compressed video

X. Shi, Shanghai Univ. (China)

Moving object retrieval technique in compressed domain plays an important role in many real-time applications, e.g. Vehicle Detection and Classification. A number of retrieval techniques that operate in compressed domain have been reported in the literature. H.264/AVC is the up-to-date video-coding standard that is likely to lead to the proliferation of retrieval techniques in the compressed domain. Up to now, few literatures on H.264/AVC compressed video have been reported. Compared with the MPEG standard, H.264/AVC employs several new coding block types and different entropy coding method, which result in moving object retrival in H.264/AVC compressed video a new task and challenging work. In this paper, an approach to extract and retrival moving traffic object in H.264/AVC compressed video is proposed. Our algorithm first Interpolates the sparse motion vector of p-frame that is composed of 4*4 blocks, 4*8 blocks and 8*4 blocks and so on. After forward projecting each p-frame vector to the immediate adjoint I-frame and calculating the DCT coefficients of I-frame using information of spatial intra-prediction, the method extracts moving VOPs (video object plan) using an interactive 4*4 block classification process. In Vehicle Detection application, the segmented VOP in 4*4 block-level accuracy is insufficient. Once we locate the target VOP, the actual edges of the VOP in 4*4 block accuracy can be extracted by applying Canny Edge Detection only on the moving VOP in 4*4 block accuracy. The VOP in pixel accuracy is then achieved by decompressing the DCT blocks of the VOPs. The edge-tracking algorithm is applied to find the missing edge pixels. After the segmentation process a retrival algorithm that based on CSS (Curvature Scale Space) is used to search the interested shape of vehicle in H.264/AVC compressed video sequence. Experiments show that our algorithm can extract and retrival moving vehicles efficiency and robustly.

6246-30, Poster Session

Application of DSP in the image transmission system

G. Feng, Huaqiao Univ. (China)

Digital signal processor is one of the most important devices in the field of real-time signal processing. Using DSP to realize static image and video compression has become one of the research focuses in domain of information science. How to combine advanced and high-efficient picture compress technology with the powerful data processing ability of DSP to develop the practical image transmission system is one of the hot points now.

A scheme to realize static image and video code and decode based on TI DSP chip TMS320C6416 was proposed in this paper, and a reliable image transmission system was developed.

According to the demand, the software has six major modules: (1)initialization of DSP chip and other hardware; (2)video acquisition and input control program, which enable obtain the video or picture from camera or other resource; (3)serial port communicating program, for the purpose of data flow in or out between DSP system and the computer; (4)RAM storage and communicating program that applies and releases the token-ring, which enable CPU to transfers data in high speed and needn't waiting for the next work period; (5)video reconstruct and output control program, the program reconstructs decoding data flow to video and enable output the video or image; (6) the major parts of the software— encoding and decoding program, in which wavelet was applied first, then run length coding and Huffman coding were carried out, the image or video could had balance resolution and better visual effect by adaptive processing, in the decoding parts, the reverse operation were executed.

After the system line up debugging was carried out, a satisfying result was reached: the comparatively high compression rate, preferable image quality and relatively real-time result.

6246-31, Poster Session

Object-oriented digital imaging technology

S. Nishida, Fourie, Inc. (Japan)

I would like to propose a new imaging technology that has full digital non-scanning image format. The significant characteristic of this technology is that it allows the digital architecture of image objects deviation in space and over time. Consequently, this is not subject to hardware definitions with regard to either image input or display equipment. In brief, this treats unlimited resolution image, free from the current scanning or frame numbers restriction, and has simple philosophy both for still and moving picture.

This technology is fitted to various types and any definition flat panels, higher resolutions image sensors and computer networks especially to packet network, and applied for future display such as e-paper. So that this innovation technology is suitable for the coming ubiquitous world

To describe an image data, I define a normalized division method of image plane and assign the level bits and address bits of divided blocks. Then image object is described with plural large and small blocks. This is so-called object-oriented. As for moving picture, only changing part is described by bits with time code replaced by frames, resulting in the moving image data is not increased.

Furthermore, this technology applies to image object recognition and tracking, it is effective both for high-speed object capture and for ultra-high definition. The application is for robotic vehicles, medical imaging and other systems. The encryption tightens and has a strong cryptographic technology because of frameless bits stream.

6246-32, Poster Session

A new error resilience method for FGS video enhancement bitstream

M. Ran, Z. Zhang, Shanghai Univ. (China)

Fine Granular Scalability (FGS), a new scalable video coding scheme, provides very fine scalability when IP-based video communication suffers from. bandwidth fluctuation. Typically, the FGS video encoder generates two bitstreams: a base layer (BL) and an enhancement layer (EL). The BL provides low quality of reconstructed image and fits in a small bandwidth. The EL bitstream can be truncated into any number of bits according to the variation of the bandwidth.

Despite the scalability provided by FGS, channel errors, especially the loss of packets, are still in existence. For the extremely high importance of the BL bitstream, the BL is heavily protected to guarantee lossless transmission. And the error concealment methods based on traditional motion compensated DCT transform coding schemes are suitable for the BL. To the EL, it usually has little error protection since it is not more important than the BL. And the traditional error concealment is not suitable to the EL because of its using bit plane coding. When the EL happens loss, the residual bitstream will be discarded. It is necessary to provide some error protections to the EL to improve the quality of reconstructed image highly.

On the one hand, the EL is the quantized difference between the original frame and the BL reconstructed frame. The EL has no temporal error spreading since it uses intra-coding, which limits the impact of losing EL bitstream to the current frame and does not influence the other frames. On the other hand, when the current frame is very similar to the previous frame, the current EL will be much closer to the previous one. Due to different importance of different bit planes, the MSB (most significant bit-plane), MSB1 or MSB2 have more important than other MSBs. When the some of the bit planes in the current frame are lost, all or part of the previous EL can be directly or indirectly replaced to the current lost EL in terms of the different importance of the lost MSBs. Simulation results show the EL using the new method has stronger error resilience capability to achieve higher image quality.

6246-33, Poster Session

A fast context-based adaptive binary arithmetic coding algorithm in H.264/AVC

G. Xiao, Shanghai Municipal Educational Examinations Authority (China); X. Shi, Shanghai Univ. (China)

Abstract: Context-based Adaptive binary Arithmetic Coding (CABAC) is a new entropy coding method presented in H.264/AVC that is highly efficient in video coding. In the method, the probability of current symbol is estimated by using the wisely designed context model, which is adaptive and can approach to the statistic characteristic. Then an arithmetic coding mechanism largely reduces the redundancy in inter-symbol. Compared with UVLC method in the prior standard, CABAC is complicated but efficiently reduce the bit rate. Based on thorough analysis of coding and decoding methods of CABAC,This paper proposed two methods, sub-table method and stream-reuse methods, to improve the encoding efficiency implemented in H.264 JM code. In JM, the CABAC function produces bits one by one of every syntactic element. Multiplication operating times after times in the CABAC function lead to it inefficient. The proposed algorithm creates tables and classes them into several types beforehand and then produce every bits of syntactic element. In JM, intra-prediction and inter-prediction mode selection algorithm with different criterion is based on RDO(rate distortion optimization) model. One of the parameter of the RDO model is bit rate that is produced by CABAC operator. After intra-prediction or inter-prediction mode selection, the CABAC stream is discard and is recalculated to output stream. The proposed Stream-reuse algorithm puts the stream in memory that is created in mode selection algorithm and reuses it in encoding function. Experiment results show that our proposed algorithm can averagely speed up 1.5 to 2 times higher speed individually compared with the original CABAC algorithm of JM at the cost of only a little memory space.

6246-34, Poster Session

Secure multimedia browser over network

S. Lian, France Telecom R&D Beijing (China)

With the innovation of network technology and the improvement of real-time multimedia processing, multimedia data are widely used in human being's life. Accessing whenever and wherever is expected. In this environment, how to protect real-time media becomes urgent. Generally, both security and efficiency should be satisfied. As a alternative to protect real-time video, a secure multimedia browsing scheme is presented here. In this scheme, the server encrypts multimedia data to be sent with perceptual encryption algorithm based on Advanced Video Coding (AVC) that is widely used in IPTV, the customers decrypt the received multimedia data during decoding process and display the decoded pictures or audios, and both of them are under the control of encryption key and quality factor. According to quality factor, customers can be classified into several types who can watch multimedia data of different quality. Some analyses and experimental results are given to show its practice. This scheme can be used in secure multimedia sharing over Internet or wireless network, such as Video-on-Demand (VOD) system, Audio-on-Demand (AOD) system, pay-TV, videoconferencing systems, wireless or mobile multimedia, etc.

6246-35, Poster Session

A new approach of edge detection based on pyramid-structure wavelet transform

S. Yi, H. Cao, M. Liu, X. Li, Huazhong Univ. of Science and Technology (China)

Singularity detection and processing of image receives broad applications in denoising, edge detection and image compression. Its application in edge detection shows more effective suppression against noise and provides the fundamental for many further applications, such as robotic vision. However, in the traditional approaches of edge detection with singularity, due to Lipschitz estimation in the continuous or dyadic wavelet transform, the computation burden is high. Meanwhile, each multi-scale edge is usually treated separately and the edge in coarser scale receives few attentions in edge detection. In this paper, we propose a new approach of edge detection with singularity that is based on pyramid-structure wavelet transform and utilizes the correlations among multi-scale edges. To reduce the computation burden, the pointwise Lipschitz is estimated in pyramid-structure wavelet transform. To synthesize the multi-scale edge which composes of edge-related wavelet modules, we utilize the strong correlation of wavelet coefficients across multi-scales in pyramid structure. In fact, with respect to Maximum Modules Chain obtained in Lipschitz estimation, the edge in coarser scale implicates the appearance of edge of similar direction in corresponding region in the finer scale. By iterating the process of edge detection under the guidance of the edge in coarser scale from low resolution to the original resolution, the edge of the original image is extracted with considerable accuracy and continuity. Our experiment states that the Lipschitz estimation in our method is accurate enough to discriminate edge and noise while the computation burden is reduced and the error of edge detection is no more than one pixel.

6246-36, Poster Session

Characterization of ultraresolution method

E. N. Terentiev, M.V. Lomonosov Moscow State Univ. (Russia); N. E. Terentiev, PointBreak.ru (Russia)

The Fredholm equation of the first kind has been ordinary used in tasks of compensation for PSF distortion. However, there exist some contradiction. Namely, the distortion in any definite point depends on a small amount adjacent points. Meanwhile, the task of compensation is set forth for image as a whole, i.e. for a large amount of points.

The ultra-resolution method does not make use of the Fredholm equation of the first kind. The PSF distortions are compensated point by point [1,2]. The method can be used at low signal/noise ratio.

The characterization of ultra-resolution method is connected with the investigation the value of compensated distortions in dependence on the noise level and on the pass band frequency of method.

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6246-37, Poster Session

Arithmetic for color image morphological transform

W. Q. Lin, Huaqiao Univ. (China)

Morphology is an importance method in image processing and computer vision technique. Now as we know that morphology has been widely used in grayscale and bi-level image processing, but it is difficult to use in color image processing, for color image has three color components. Applying morphological method on color image may cause color shift in the original image. Morphological image processing method has satisfactory results in noise restraining, image enhancing, image encoding, feature ex-

tracting, and texture analyzing. So it is important to find out a method for applying morphological method on color image, and keep the color unchanged at the same time. An approach for color image morphological transform was put forward in this paper. In our approach, we change the color model from RGB space to HIS space first, then applying morphological transform on I component in HSI space and keeping H and S components unchanged, finally using new I component and two other components to obtain color image in RGB space. For color image morphological transform, some new color morphological operators were defined in this paper, and their characters were discussed. Experimental results were also explained in the paper. Color morphological transform is a prolonging application of morphology in color space. We find it is an effective means in image processing and feature extracting of target shape.

6246-38, Poster Session

A new texture representation with multiscale wavelet feature

S. Yi, H. Cao, M. Liu, X. Li, Huazhong Univ. of Science and Technology (China)

Textures are important characteristics for object identification and texture analysis is fundamental for many applications such as industrial monitoring, remote sensing and medical diagnosis. The existing methods for texture modeling include co-occurrence statistics, filter banks and random fields. However most of these methods lack of capability to characterize the different scale of texture effectively. Some approaches based on wavelet transform have been proposed to avoid such a problem by utilizing the energy or other feature in different scale or frequency bands but the phase of the wavelet modules and the correlation of the extracted features across multi-scales receive few attentions. In this paper, we propose a texture representation which combines both amplitude and phase of wavelet modules in multi-scale. In fact, the self-similarity of texture could be measured in both correlations across the multi-scale and statistical feature within a single-scale. In our approach, for each scale, the statistical measurement of amplitude is extracted to represent the energy within the corresponding frequency band; the statistical measurement of the phase of modules is extracted to represent the texture's orientation. Moreover, the evolution of the above features with respect to the increase of scale is measured as another representation of the self-similarity of texture. Our experiment indicates that, in the proposed texture representation the distance of different texture patterns is larger than the one of the traditional features.

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6247-31, Session 7

Performance evaluation based on cluster validity indices in medical imaging

A. Meyer-Bäse, Florida State Univ.

Exploratory data-driven methods such as unsupervised clustering are considered to be hypothesis-generating procedures, and are complementary to the hypothesis-led statistical inferential methods in functional magnetic resonance imaging (fMRI). The major problem with clustering of real bioimaging data is that of deciding how many clusters are present. This motivates the application of cluster validity techniques in order to quantitatively evaluate the results of the clustering algorithm. In this paper, we apply three different cluster validity techniques, namely, Kim's index, Calinski Harabasz index, and the intraclass index to the evaluation of the clustering results of fMRI data. The benefits and major limitations of these cluster validity techniques are discussed based on the achieved results of several datasets.

6247-32, Session 7

Classification of infrasound events using hermite polynomial preprocessing and radial basis function neural networks

C. G. Lowrie, F. M. Ham, Florida Institute of Technology

A method of infrasonic signal classification using hermite polynomials for signal preprocessing is presented. Infrasound is a low frequency acoustic phenomenon typically in the frequency range 0.01 Hz to 10 Hz. Data collected from infrasound sensors are preprocessed using a hermite orthogonal basis inner product approach. The hermite preprocessed signals result in feature vectors that are used as input to a parallel bank of radial basis function neural networks (RBFNN) for classification. The spread and threshold values for each of the RBFNN are then optimized. Robustness of this classification method is tested by introducing unknown events outside the training set and counting errors. The hermite preprocessing method is shown to have superior performance compared to a standard cepstral preprocessing method.

6247-33, Session 7

A zero-watermarking algorithm based on DWT and chaotic modulation

H. Cao, Huazhong Univ. of Science and Technology (China)

With the development of information technology and digital network communications, usage of digital media has a tremendous growth, as a result of their notable benefits in efficient storage and easy of transmission. However these features make digital media vulnerable to copyright infringement, tampering and unauthorized distribution. Recently the protection of digital information has received significant attention and lots of techniques have been proposed [1-4]. In the traditional methods of watermarking images, the watermarking is embedded an original image, and the watermarking information can be extracted with the secret key. Most methods of watermarking, no matter in spatial domain or frequency domain, modify the original data while embedding the watermark. The secret information is embedded for authority protection but distort the original information at the same time. This reflects a conflict between invisibility and robustness. Is there any approach to remove this conflict?

The answer is YES, if we just construct the watermark based on the essential characters of image but not to modify the data or original image. Such approach that modifies no original data is called zero-watermarking [5]. Zero-watermarking can successfully solve the conflict between invisibility and robustness.

In this paper, we propose a new method of zero-watermarking based on discrete wavelet transform and chaotic modulation. The watermark is determined by the character of wavelet coefficients extracted from the low frequency sub-band in the wavelet domain of the original image. The locations of the wavelet coefficients being selected are determined by the chaotic sequence (generated by Logistic Equation). Our experimental results prove that our method of watermarking attains a high quality of invisibility and robustness. The attack experiments, such as mean filter, JPEG lossy compression, additive Gaussian noise, cropping attacks and rotation attacks, give strong evidences for the robustness of our method. In comparison with the traditional watermarking approaches that will modify the original data more or less, this method can provide a watermarked image without any distortion in original data and attain great performance in security protection. Without any knowledge of initial value of the chaotic sequence, it is impossible to extract the watermark.

The method of zero-watermarking proposed in this paper has some virtue as follow:

(1)Change no data in the original image and gain high imperceptibility;

(2)The wavelet transform is only used to generate wavelet coefficients in low frequency sub-bands and the invert transform is not needed. This way, the numerical error is avoided and the watermark being extracted should be of no distortion;

(3)The chaotic modulation is used to generate the character watermark and it is impossible to extract the character watermark without any knowledge about the initial value. This provides high security.

(4)The robustness against various attacks is strong.

6247-01, Session 1

Discrete wavelet transform FPGA design using MatLab/Simulink

U. H. Meyer-Bäse, Florida State Univ.; A. Vera, M. S. Pattichis, The Univ. of New Mexico; A. Meyer-Bäse, R. J. Perry, Florida State Univ.

Field-programmable gate arrays (FPGAs) are on the verge of revolutionizing digital signal processing. Many front-end digital signal processing (DSP) algorithms, such as FFTs, multi channel filterbanks, or wavelets, to name just a few, previously built with ASICs or programmable digital signal processors, are now most often replaced by FPGAs.

The two FPGA market leaders (Altera and Xilinx) both report revenues greater than $1 billion. FPGAs have enjoyed steady growth of more than 20% in the last decade, outperforming ASICs and PDSPs by 10%.

Design of current DSP applications using state-of-the art multi-million gates devices requires a broad foundation of the engineering skills ranging from knowledge of hardware-efficient DSP algorithms to CAD design tools. The requirement of short time-to-market, however, requires to replace the traditional HDL based designs by a MatLab/Simulink based design flow. This not only allows the over 1 million MatLab users to design FPGAs but also to by-pass the hardware design engineer and therefore a large reduction in development time.

Critical however with this design flow are: (1) quality-of-results, (2) sophistication of Simulink block library, (3) compile time, (4) cost and avail-

ability of development boards, and (5) cost, functionality, and easy-to-use of the FPGA vendor provided design tools.

We have evaluated several different wavelet filter bank approaches for the Altera and Xilinx design flow and will present the results regarding the above 5 criteria in this paper.

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6247-02, Session 1

Nonrectangular wavelets for multiresolution mesh analysis and compression

A. E. Cetin, Bilkent Univ. (Turkey)

Meshes are widely used in computer graphics and visualization of three-dimensional (3-D) graphics and objects. 3-D objects and their mesh representations in graphics are either artificially created or obtained by using 3-D scanning and acquisition devices. Such devices typically create mesh triangulations representing an arbitrary topology. The large size of the meshes makes it difficult to manipulate such objects efficiently even in powerful computer systems. Also, the demand for online accessing of graphics data requires rapid ways of transmission and progressive mesh representations. Multiresolution representation of mesh data provides an efficient way of progressive representation of complex objects.

A mesh can be considered as an irregularly sampled discrete signal in space. In a given 3-D mesh data, vertex coordinates represent the mesh grid point. The main problem of processing this kind of data with a wavelet filterbank is the irregularity of the data. In our approach, we convert the mesh into a regularly sampled signal by putting a grid structure on the space and have a differential representation of the mesh data on the regular quincunx grid. Each quincunx grid node is assigned a 3-D value defined as the vector starting from the quincunx grid node to the actual location of the nearest mesh vertex. In this way, each vertex point of the mesh is assigned to a grid point in the quincunx grid and quincunx grid nodes have vector values representing the distance to the actual mesh grid point. This is a 3D image like representation of the original mesh on a quincunx grid and a wavelet filterbank on the quincunx grid can be used to analyze a given mesh in a multiresolution framework.

Since the meshes are triangulations of the space it is better to use a quincunx or a hexagonal grid and filterbanks instead of a rectangular grid.

Multiresolution mesh manupilation and mesh coding examples will be presented in the final form of the paper.

6247-03, Session 1

Sensor and system health management simulation

A. M. Amini, Southern Univ.

The health of a sensor and system is monitored by information gathered from the sensor. First, a normal mode of operation is established. Any deviation from the normal behavior indicates a change. Second, the sensor information is simulated by a main process, which is defined by a step-up, drift, and step-down. The sensor disturbances and spike are added while the system is in drift. The system runs for a period of at least three time-constants of the main process every time a process feature occurs (e.g. step change). The wavelet Transform Analysis is performed on three sets of data. The three sets of data are: the simulated data described above with Poisson distributed noise, real Manifold Pressure data, and real valve data. The simulated data with Poisson distributed noise of SNRs ranging from 10 to 500 were generated. The data are analyzed using continuous as well as discrete wavelet transforms. The results indicate distinct shapes corresponding to each process.

6247-04, Session 1

Invariant lattice variational principles for image compression and denoising with wavelets

R. C. Venkatesan, Systems Research Corp. (India)

A correspondence between soft wavelet thresholding [1] and stabilized inverse diffusion equations (SIDE) [2] is established. SIDE represent a discrete space continuous time representation of discontinuity preserving image segmentation and denoising. A self-consistent variational principle the wavelet/lattice PDE combine for the discrete Haar wavelet ansatz and SIDE's with a total variation (TV) force function is derived using a modified version of the Discrete Variational Complex [3] inspired by T. D. Lee. The law of conservation of total energy is obtained from Noether's theorem for the wavelet/PDE model defined in lattice space. The case of a two-pixel image is analyzed, and, comparisons drawn to the discretized Rudin-Osher-Fatemi TV denoising theory, and, TV diffision models [4]. A self-consistent dynamic representation of wavelet/PDE denoising and compression in lattice space is provided. The lattice variational principle is shown to represent a case where the segmentation is performed by the SIDE model, and denoising by compression is accomplished by FIR filter banks. This represents the converse scenario to the wavelet compression model of Chan and Zhou [5]. The model is extended to cases involving higher resolution, by the downward traversal of the Laplacian (image) pyramid. Numerical examples for exemplary cases are presented.

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6247-05, Session 1

Cross-sensor fusion of imagery for improved information extraction

S. P. Kozaitis, M. Ouendeno, Florida Institute of Technology

We combined cross-sensor data that leads to improved extraction of information from disparate sensors. In our approach, we devise a set of forward wavelet transforms, optimized to preserve the individual information content of each sensor image followed by a common inverse transform that is designed to preserve the most desirable information characteristics of each image after fusion. Using the method described here, we expect to reconstruct a fused image that will retain the information content in disparate domains while enhancing the information content of the fused image product. This approach is quite novel and challenging because an optimal inverse transform from two different forward transforms has not been devised. Our approach takes full advantage of the fundamental properties of the wavelet transform and has broad applicability to many types of sensor data fusion problems. Anywhere sensors with different characteristics can be used, our method can be applied. For example, tracking, mulitsource tracking, and handing-off between sensors. We intend to demonstrate one application, that of the fusion of visible and infrared imagery to prove our assertion.

6247-06, Session 1

Implementation of an adaptive wavelet system for distortion correction in smart interferometric sensors

K. J. Jones, Rice Univ.

Interferometric sensors are effective for monitoring shape, displacement or deformation in Smart Structures. Wavelet-based ridge extraction will be applied to determine phase (and superimposed noise) in 1-D signals from 2-D interferograms. A second wavelet system, an adaptive wavelet system, will be designed and implemented to achieve distortion correction, analogous to adaptive wavelet echo cancellation.

The measurement of shape and displacement can be carried out using interferometric techniques, achieving high spatial and temporal resolution. The goal is to achieve real-time measurments under dynamic conditions. Phase can be determined using the Morlet wavelet transform. Correction of phase distortion is achievable by phase conjugation since distortion is known to be carried on the phase term.

Adaptive systems are important when signals or environments are changing in time. Using wavelets in an adaptive system is an interesting challenge. Using wavelets for echo cancellation is a particularly good example of using adaptive wavelets in a dynamic system. An adaptive wavelet systems for achieving distortion cancellation in phase from interferograms will be designed and implemented. Noise is usually high frequency, while signal is low frequency. However, with interferograms, a sharp signal becomes broaded when distorted. Wavelet-based ridge extraction can determine phase with added distortion. Adaptive wavelets will cancel distortion yielding a corrected signal.

Wavelet-based ridge extraction will be applied to 1-D signals in 2-D interferograms to determine phase (and added distortion). A sequence of 1-D signals will be used to detect deformation in Smart Structures. Analogous to adaptive wavelet echo cancellation, an adaptive wavelet system will be designed and implemented to cancel interferometric distortion in Smart Interferometric Sensors.

6247-07, Award Session

Blind source separation of convolutive mixtures

S. Makino, Nippon Telegraph and Telephone Corp. Communication Science Lab. (Japan)

Review of frequency-domain blind source separation (BSS) of convolutive mixtures of acoustic signals, especially speech, is given. A statistical and computational technique, called independent component analysis (ICA), is examined. By achieving nonlinear decorrelation, nonstationary decorrelation, or time-delayed decorrelation, we can find source signals only from observed mixed signals. Particular attention is paid to the physical interpretation of BSS from the acoustical signal processing point of view. Frequency-domain BSS is shown to be equivalent to two sets of frequency domain adaptive microphone arrays, i.e., adaptive beamformers (ABFs). Although BSS can reduce reverberant sounds to some extent in the same way as ABF, it mainly removes the sounds from the jammer direction. This is why BSS has difficulties with long reverberation in the real world.

If sources are not “independent,” the dependence results in bias noise when obtaining the correct separation filter coefficients. Therefore, the performance of BSS is limited by that of ABF with correct prior knowledge.

Although BSS is upper bounded by ABF, BSS has a strong advantage over ABF. BSS can be regarded as an intelligent version of ABF in the sense that it can adapt without any information on the source positions or period of source existence/absence.

6247-08, Session 2

Interference and noise-adjusted principal components analysis for hyperspectral remote sensing image compression

Q. Du, Mississippi State Univ.; H. H. Szu, The George Washington Univ.

Hyperspectral remote sensing images have high spectral resolution that enables accurate object detection, classification, and identification. But its vast data volume brings about problems in data transmission, data storage, and data analysis. How to reduce the data volume while keeping the important information for the following data exploitation is a challenging task. Principal Components Analysis (PCA) is a typical method for data compression, which re-arranges image information into the first several principal component images in terms of variance maximization. But we know variance is not a good criterion to rank images. Instead, signal-to-noise ratio (SNR) is a more reasonable criterion, and the resulting PCA is called Noise Adjusted Principal Components (NAPC) analysis. It is also known that interference is a very serious problem in hyperspectral remote sensing images, coming from many unknown and unwanted signal sources extracted by hyperspectral sensors. Signal-to-interference-plus-noise (SINR) was proposed as a more appropriate ranking criterion. The resulting PCA is referred to as Interference and Noise Adjusted PCA (INAPCA). In this paper, we will investigate the application of NAPC and INAPCA to hyperspectral image compression. The focus is the analysis of their impacts on the following data exploitation (such as detection and classification). It is expected that using NAPC and INAPCA higher detection and classification rates can be achieved with a higher compression ratio. The results will be compared with popular wavelet-based compression methods, such as JPEG 2000, SPIHT, and SPECK.

6247-09, Session 2

Unsupervised unmixing of hyperspectral imagery using the constrained positive matrix factorization

Y. M. Masalmah, M. Vélez-Reyes, Univ. de Puerto Rico Mayagüez

In hyperspectral imagery (HSI), hundreds of images are taken at narrow and contiguous spectral bands providing us with high spectral resolution spectral signatures that can be used to discriminate between objects. In many applications, the measured spectral signature is a mixture of the target of interest, clutter and other objects within the field of view of the sensor. In order to determine which object is in the field of view of the sensor, we can use the high spectral resolution information to decompose the measured spectral signature in its constituents and their contribution to the measured spectra. This is the so called unmixing problem. This paper presents an approach for simultaneous determination of endmembers and their abundances in hyperspectral imagery using a constrained positive matrix factorization. The algorithm presented here solves the constrained PMF by formulating it as a nonnegative least squares problem where the cost function is expanded with a penalty term to enforce the sum to one constraint. Preliminary results using NASA HYPERION imagery data are presented. The results show the potential of the method to solve the unsupervised unmixing problem.

6247-10, Session 2

A priori ICA as a fisher game

R. C. Venkatesan, Systems Research Corp. (India)

The LCNN A-Priori ICA model is cast within the scope of the Frieden-Soffer measurement-response scenario as a Fisher game. The game is played between an observer who inhabits the measurement space and the system under observation.

Variational minimization of the Lagrangian yields a Schroedinger-like equa-

tion. The learning rule is obtained by enforcing that the contrast term (the Fisher information) evolves along a geodesic defined on a Fubini-Study metric, in conjunction with SVD.

Suggestions to extend the above formulation to a Hamilton-Jacobi formulation are provided. The Hamilton-Jacobi model is intended to overcome the "curse of dimensionality", by utilizing the level set method. Numerical examples for exemplary cases are presented.

6247-11, Session 4

Detecting low-frequency functional connectivity in fMRI using self-organized algorithms

A. Meyer-Bäse, Florida State Univ.

Recent research in functional magnetic resonance imaging (fMRI) revealed slowly varying temporally correlated fluctuations between functionally related areas. These low-frequency oscillations of less than 0.08 Hz appear to have the property of symmetric cortices, and they are known to be present in the motor cortex among others. These low-frequency data are difficult to detect and quantify in fMRI. Traditionally, user-based regions of interests (ROI) or "seed clusters" have been the primary analysis method. We propose in this paper to employ self-organized algorithms to detect the resting state of functional connectivity. There are two main benefits using self-organized algorithms instead of traditional techniques: (1) the scan time is reduced by finding directly the activation data set, and (2) the whole data set is considered and not a relative correlation map. The achieved results are compared with those found using seed clusters. Thus, we are able to detect functional connectivity based on model-free

6247-12, Session 4

A biologically inspired neural oscillator network for geospatial analysis

R. S. Rand, U.S. Army Engineer Research and Development Ctr.; D. Wang, The Ohio State Univ.

A biologically plausible neurodynamical approach to scene segmentation based on oscillatory correlation theory is investigated. A network of relaxation oscillators, which is based on the Locally Excitatory Globally Inhibitory Oscillator Network (LEGION), is constructed and adapted to geospatial data with varying ranges and precision. This nonlinear dynamical network is capable of achieving segmentation of objects in a scene by the synchronization of oscillators that receive local excitatory inputs from a collection of local neighbors and desynchronization between oscillators corresponding to different objects. The original LEGION model is sensitive to several aspects of the data that are encountered in real imagery, and achieving good performance across these different data types requires the constant adjusting of parameters that control excitatory and inhibitory connections. In this effort, the connections in the oscillator network are modified to reduce this sensitivity with the goal to eliminate the need for parameter adjustment. We assess the ability of the proposed approach to perform natural and urban scene segmentation for geospatial analysis. Our approach is tested on simulated scene data as well as real imagery with varying gray shade ranges and scene complexity.

6247-14, Session 4

Unsupervised polarization sensors fusion of polarization signals produced by scattering by reflection from the air/water interface

M. Kurum, H. H. Szu, The George Washington Univ.

Biological signals that use color, pattern, brightness, and motion are well known. Of the three fundamental properties of light (intensity, wavelength, polarization), polarization is the least known to the general public. Humans are essentially insensitive to the polarization characteristics of light. However, the ability to analyze polarized light is widespread among animals. Some animals make use of the polarized light in the underwater world, on the water surface, and in the sky. Light arriving from the sun and moon is fully depolarized, consisting of mixtures of photons having randomly oriented electric filed vector. As the light passes through some natural madiums, it becomes partially linearly polarized light. Polarization sensitive animals will use this polarization information in their visual worlds. It seems pertinent to ask how all these ways of exploiting polarized-light information can be utilized to make artificial sensors such as contrast enhancement and haze reduction, breaking camouflage, optical signaling, detecting particular polarization as compass. A recent investigation of Frog eyes indicating the importance of a pair of Frog eyes equipped each with a horizontal periodic slits across middle of pupil. It was shown (e.g. Nova national Geographical field trip movie) a Frog can accurately catch above the surface of muddy pound flying insets as big as a small bird. Thus, the unsupervised polarization sensors fusion to enhance the SAN ratio will be studied in this paper.

6247-15, Session 4

Thermodynamic energy minimization approach to breast cancer detection

L. Miao, H. Qi, The Univ. of Tennessee; H. H. Szu, Office of Naval Research

In this paper, we propose an unsupervised subpixel breast cancer detection algorithm, which enhances both the sensitivity and accuracy of traditional cancer diagnosis technique. Thermal breast scanning has been employed for a number of years, which however is limited to a single infrared band. In this research, we propose to use two cameras at different infrared wavelengths (Medium wavelength IR (3-5um) and Long wavelength IR (8-12um)) to transcribe the thermal diffusion process into two images. Based on the Plank radiation law, the imaging process follows a linear mixture model. That is, each measured data vector can be viewed as a linear combination of the abnormal and normal cells at different wavelength range. Beyond that, breast cancer detection problem is reduced to mathematical spectral vector analysis. Current researches on spectral unmixing seem to serve this purpose. However, only two spectral bands are available for cancer detection application, which cannot satisfy the non-degeneracy assumption in spectral unmixing literature.

In this paper, we propose an energy minimization approach for subpixel cancer detection. Based on the second law of thermodynamics, we set up an objective function which minimizes the Helmholtz free energy. The information energy is defined as a function of observation and is calculated based on neighborhood information. The experiments demonstrate the effectiveness of the proposed method. The physics constraints of free energy minimization have achieved sub-pixel accuracy. In addition to detecting the existence of cancer cell, the algorithm is able to reveal the abundance fraction of normal and abnormal constitutes.

6247-16, Session 4

Simplifying Hill-based muscle models through generalized, extensible fuzzy heuristic implementation

A. J. O'Brien, Strategic Analysis, Inc.

Traditional dynamic muscle models based on work initially published by A. V. Hill in 1938 often rely on high-order systems of differential equations. While such models are very accurate and effective, they do not typically lend themselves to modification by clinicians who are unfamiliar with biomedical engineering and advanced mathematics. However, it is possible to develop a fuzzy heuristic implementation of a Hill-based model that offers several advantages over conventional state equation approaches. Because a fuzzy system is oriented by design to describe a model in linguistics rather than mathematics, the resulting fuzzy model can be more readily modified and extended by medical practitioners who do not use differential equations and who are not biomedical engineers. It also stands to reason that a well-designed fuzzy inference system can be implemented with a degree of generalizability not often encountered in traditional state space models. Taking electromyogram (EMG) as one in-

put to muscle, this model is tantamount to a fuzzy EMG-to-muscle force estimator that captures dynamic muscle properties while providing robustness to partial or noisy data. One goal behind this approach is to encourage clinicians to rely on the model rather than assuming that muscle force as an output maps directly to smoothed EMG as an input. A strong advantage is that the model's force estimate is more accurate than assuming force equal to smoothed EMG because the model provides a transfer function that accounts for muscle's inherent nonlinearity. Furthermore, employing fuzzy logic should provide the model with improved robustness over traditional mathematical approaches.

6247-17, Session 5

Classifying launch/impact events of mortar and artillery rounds utilizing DWT-derived features and feedforward neural networks

M. E. Hohil, S. V. Desai, A. Morcos, U.S. Army Research, Development and Engineering Command

Feature extraction methods based on the discrete wavelet transform (DWT) and multiresolution analysis are used to develop a robust classification algorithm that reliably discriminates between launch and impact artillery and/or mortar events via acoustic signals produced during detonation. Distinct characteristics are found within the acoustic signatures since impact events emphasize concussive and shrapnel effects, while launch events are similar to explosions and are designed to expel and propel an artillery round from a gun. The ensuing blast waves are readily characterized by variations in the corresponding peak pressure and rise time of the waveform, differences in the ratio of positive pressure amplitude to the negative amplitude, variations in the prominent frequencies associated with the varying blast events and variations in the overall duration of the resulting waveform. Unique attributes can also be identified that depend upon the properties of the gun tube, projectile speed at the muzzle, and the explosive/concussive properties associated with the events. In this work, the discrete wavelet transform is used to extract the predominant components and distinct characteristics from the aforementioned acoustic signatures at ranges exceeding 1km. The resulting time-frequency decomposition of the acoustic transient signals are used to produce a separable feature space representation. Highly reliable classification is achieved with a feedforward neural network classifier trained on a sample space derived from the distribution of wavelet coefficients and higher frequency details found within different levels of the multiresolution decomposition. The neural network developed herein provides a capability to classify events (as either launch or impact) with an accuracy that exceeds 97%.

6247-18, Session 5

Global constrained optimization by simulated annealing using parallel

B. Noaman, H. H. Szu, The George Washington Univ.

Stochastic Neural Networks Based on Stochastic Analysis has begun with Sejnowski Boltzmann Machince in 1980 & Szu Fast Cauchy machine in 1990, which have an increase interest in the design and analysis of neural network system that take the advantage of a quenched thermal noise and cooling schedule of a controlled thermal noise. It is very important to study thermal noise and study how it affects the signal in order to better understand a system. This paper will discuss a theoretical framework of designing a stochastic neural network. The stochastic aspects of noise will be studied via the Newton equation of Brownian motions, so-called Langevin equation via Fokker-Planck equation embedded in Artifical Neural Networks stochastic equation of motion with added thermal noise as a function of time. Application in sensor fusion will be illustrated for automatic unsupervised of a pair of sensors feature extraction.

6247-19, Session 5

Chaotic associative memory and private V-mails

P. D. Baier, H. H. Szu, M. Hsu, The George Washington Univ.

Abstract — To support third generation cellular phones with broadband wireless video emails (V-mails), we develop a Chaotic Neural Network (CNN) Associative Memory whose typing and initial value are sent by the RSA public key algorithm. The RSA patent has expired, and this algorithm can be used license- and royalty-free. Receiver devices with the embedded system chip use their private RSA key to decrypt the so called spatial-temporal keys (STK), which can then be used to recreate the chaotic series needed for the transmission to be correctly decrypted. The cryptographic security of the chaotic map is discussed. The basic chaotic series is shown to have certain statistical weaknesses which make it insecure. We therefore discuss some ways of improving its properties. Due to the fading and fatal noise in wireless communication channel, the STK must be robust and fault-tolerant. This is ensured by a property of CNNs proven by a field theory of Associative Memory and demonstrated by Szu.

6247-21, Session 5

Wavelet application in hearing process and development of intelligent unsupervised hearing-aid sensors

M. Raed, The George Washington Univ.

The design and implementation of dual hearing aid is a process that combines the current three known electronic circuit technologies (analog, analog/programmable, and digital) into the realm of wavelets and neural networks, where a high dimension representation of data is condensend invariantly into a two-dimensional bi-featured information. This paper will attempt to shed light on mathematical modeling of the ear, biological propogation of sound, and replication of sound frequencies as means to design unsupervised hearing-aid sensor.

6247-22, Session 5

Smart internet search engine through 6-W representation unsupervised learning neural networks

S. Goehler, The George Washington Univ. and BriarTek Inc.; H. H. Szu, The George Washington Univ.

Current Internet Search Engine technology is limited in its ability to properly display necessary relevant information to the user. Yahoo, Google and Microsoft use lookup tables and single dimension data storage which limit the ability of users to effectively find their desired information. While these companies have improved their results the past few years by improving their existing technology and algorithms, there is a need for a next generation smart search engine that can effectively interpret the relevance of user's searches and provide the actual information requested. A smarter Internet Search engine that can effectively fulfill a user's needs is possible through the use of 6W Representation Unsupervised Learning Neural Networks.

6247-23, Session 5

Multimedia data authentication based on wavelet-domain codec

S. Lian, Z. Liu, France Telecom R&D Beijing (China)

With the wide application of multimedia data, multimedia content protection becomes urgent. Till now, various means have be reported, which can be classified into several types according to their functionalities. The means include data encryption, digital watermarking, data authentication. They are used to protect multimedia data's confidentiality, owner-

ship and integrity, respectively. For multimedia data authentication, some approaches have been proposed. For example, the multimedia data are encoded with Hash function into a string of fixed length, or only some features of the multimedia data are encoded with Hash function. Considering that multimedia data are often operated during transmission, such as recompression, A/D, D/A, adding noise, and so on, a good authentication algorithm should be robust to these acceptable operations,while sensitive to such malicious tampering as cutting, modification or pasting. Thus, the feature-based approach is preferred. In order to realize real time authentication, the algorithm combining with compression process is more attractive. Most of the proposed algorithms are based on DCT-domain codecs, such as JPEG or MPEG1/2. These algorithms can not only detect but also locate the malicious tamperings. Considering of the wide application of wavelet transformation in such popular codecs as JPEG2000, MPEG4, H.264 and AVS (Chinese Audio and Video Standard), it is necessary to study the authentication algorithms suitable for wavelet domain. In this paper, a wavelet-based media authentication scheme is proposed. According to the energy relationship between frequency subbands, feature codes are generated, which are then encoded with error-correction codes and embedded into the media data themselves. Both the feature extraction and embedding processes are controlled by secret keys. In the receiver end, two kinds of features are extracted from the media data (one from the media data, the other from the embedding domain), and then compred to determine the tampered location. This authentication scheme is robust to general recompression or adding noise, sensitive to cutting, pasting or modification, efficient in real time operation, and secure for practical applications.

6247-43, Session 5

A bio-nanorobot design for Drosophila therapeutic cloning

H. H. Szu, C. Chang, The George Washington Univ.

No abstract available

6247-24, Session 6

Turbo LMS algorithm: supercharger meets adaptive filter

U. H. Meyer-Bäse, Florida State Univ.

Adaptive digital filters (ADFs) are, in general, the most sophisticated and resource intensive components of modern digital signal processing (DSP) and communication systems.

Improvements in performance or the complexity of ADFs can have a significant impact on the overall size, speed, and power properties of a complete system.

The least mean square (LMS) algorithm is a popular algorithm for coefficient adaptation in ADF because it is robust, easy to implement, and a close approximation to the optimal Wiener-Hopf least mean square solution. The main weakness of the LMS algorithm is the slow convergence, especially for non Markov-1 colored noise input signals with high eigenvalue ratios.

Since its introduction in 1993, the turbo (supercharge) principle has been successfully applied in error correction decoding and has become very popular because it reaches the theoretical limits of communication capacity predicted 5 decades ago by Shannon. The turbo principle applied to LMS ADF is analogous to the turbo principle used for error correction decoders: First, an “interleaver” is used to minimize crosscorrelation, secondly, an iterative improvement which uses the same data set several times is implemented using the standard LMS algorithm.

In order to design turbo LMS algorithms the following was done: (1) develop and research global (block) or local (convolutional) interleavers; (2) analyze the interleaver properties, such as delay, latency, memory usage, and the resulting stability bounds for the learning rate imposed on the LMS algorithms through the interleaver; (3) develop an FPGA proof of concept SIMD processor, including software tools, that efficiently implements the different turbo LMS versions.

6247-25, Session 6

Spectroscopic modeling of nitro group in explosives

S. P. Hernández-Rivera, D. Nuñez, L. C. Pacheco-Londoño, Univ. de Puerto Rico Mayagüez

A statistic modeling of the nitro group (symmetric and asymmetric stretches) based on Partial Least Squares and coupling to Discriminant Analysis (PLS-DA) is described in this work. FT-IR and Raman Spectroscopy were used to acquire the required spectroscopic information. The model is based on the nitro group behavior for different molecular structures of explosives substances. This analysis can be used for characterizing the nitro group effect in other explosives. The delimitation of the spectroscopic properties is made with the result obtained in this model. The equipment used was a Fourier Transform Infrared Spectrometer (FT-IR) and Raman Microscopy and Minitab, OPUS and Matlab software. The techniques used in FTIR were the KBr pellet for transmission method and direct transmission in a microscope IR stage. The results demonstrate that the relative intensity and position of the nitro peaks are affected by the substance molecular structure and the chemical micro-environment in the target compound. The prediction shows that the model is adequate for the samples studied and robust in prediction of new samples.

6247-26, Session 6

PCNN preprocessor stage for the optical broadcast neural network processor

H. Lamela, M. Ruiz-Llata, M. Jiménez, M. González, Univ. Carlos III de Madrid (Spain); C. Warde, Massachusetts Institute of Technology

It is our understanding that specific neurovision hardware may improve the performance of artificial vision systems, providing desirable characteristics of low response time and portability. In that sense, we have proposed a hardware neural network for vision application based on a sequential optical broadcast interconnection scheme [“Image identification System based on the Optical Broadcast Neural Network Processor”, Applied Optics 44(12) 2366-2376 (2005)]. In this vision system, a CMOS sensor capture the image of an object, the output of the camera is introduced to the optoelectronic processor which compares the input image with a set of reference patterns and the optoelectronic processor provides the reference pattern that best match with the input image.

The neural processing system is based on a pattern matching strategy, so it is sensible to rotation, translation and scale of the objects in the image. In order to solve these problems we propose to include a hardware pre-processing stage between the image sensor and the optoelectronic classifier.

Pulse Coupled Neural Network (PCNN) offers very interesting properties to be used for vision applications [JL Johnson, ML Padgett. “Pulse-coupled neural nets: translation, rotation, scale, distortion, and intensity signal invariance for images”. Applied Optics 33(26), 6239-6523 (1994)] and they have shown that they can be implemented in hardware using quite simple analogue circuits [Y Ota, BM Wilamowski. “Analog Implementation of Pulse-Coupled Neural Networks”. IEEE trans. NN 10(3), 539-544 (1999)].

From previous references we can observe that PCNN has the ability to convert an image from its 2D spatial representation to a temporal representation. This characteristic present an advantage to our optoelectronic neural network classifier, as the input patterns must be introduced by means of a sequential representation. Additionally, the generated train pulses can be made insensitive to translation, scale, rotation, distortion and intensity, so thus improving the performance of the vision system.

In this paper we would investigate the integration of a hardware PCNN to be used as the pre-processing stage for a vision system which uses as processing core the Optical Broadcast Neural Network Processor.

6247-27, Session 6

Lightweight encryption for platforms with resource constraints

P. D. Baier, H. H. Szu, M. Hsu, The George Washington Univ.; J. M. Willey, Naval Research Lab.

Recent years have seen a rapid increase in small, relatively inexpensive devices which can store, process and transmit data, such as smart cards or wireless communication devices like remote keys and RFID chips. Such devices increasingly take over many basic functions in everyday life. For example, smart cards can store medical records, provide access to bank accounts, and control physical access to buildings. Remote keys are by now a standard accessory in cars, and RFID chips can replace bar codes on merchandise, track merchandise in transit, or store biometric data in passports.

Among the benefits of these technologies are that they are cheap, customizable, and they offer superior functionality compared to the technologies they replace. However, these technologies also have immediate privacy and data security implications which are not always fully addressed by the industry. Concerns include the illicit monitoring of individuals carrying RFIDs to the “skimming” (unauthorized retrieval) of sensitive information, for example, from biometric passports.

This paper gives an overview of the state-of-art of “lightweight” encryption. We present existing algorithms designed for “lightweight” applications, discuss their strengths and weaknesses, and estimate the level of security they offer. The paper is written to make the subject accessible to developers without specialized knowledge in cryptography and raise awareness of privacy and data security issues associated with low-power computing devices.

6247-29, Session 6

Parallel distributed RSOM tree for pattern classification

S. Xia, W. Hu, W. Yu, National Univ. of Defense Technology (China)

Data clustering requires high-performance computers to get results in a reasonable amount of time, particularly for large-scale databases. A feasible approach to reduce processing time is to implement on scalable parallel computers.

Thus, RSOM tree method is proposed. Firstly a SOM net, as the root node, is trained. Then, all trained samples are allocated to the output nodes of the root node according to WTA-criterion. Thirdly, the parameters of discriminability are calculated form the samples for each node. If discriminable, the node will be SOM-split and labeled as an internal node, otherwise an end node, and the split terminates. Recursively check or split all nodes until there is no node meeting with the discrimination criteria. Finally, a RSOM tree is obtained. In this process, several kinds of control-factors, e.g. inter-class and intra-class discrimination criteria, layer number, sample number, and correct ratio of classification, are obtained from the data in each node. Accordingly the good choice of the RSOM structure can be obtained, and the generalization capability is assured.

This RSOM tree method is of the nature of parallelism, and can be implemented on scalable parallel computers, including high performance Cluster-computers, and local or global computer networks. The former becomes more and more attractive except for its expensiveness, while the latter is much more economic rewarding, and might belong to Grid- Computation to a great extend. Based on the above two kinds of hardware systems, the RSOM algorithm has been implemented separately, and the experiment results proves the efficiency.

6247-30, Session 6

A novel multi-strategy watermark embedding technique

G. Feng, Huaqiao Univ. (China)

With the rapid growth of network distributions of information like images and etc, there is an urgent need for copyright protection against pirating. Different digital watermarking schemes had been proposed to address this issue of ownership identification. Early work on digital watermarking focused on information hiding in the spatial domain or transform domain respectively. Usually the watermark recovered result was not as satisfaction as the demand. Some multi-describing techniques were proposed for watermark embedding lately. Enlightened by these techniques, a novel blind digital image watermarking algorithm based on multi strategy is put forward in this paper. The watermark is embedded in multi-resolution wavelet transform domain of the original image. Based on spread spectrum techniques, the algorithm is composed of three new techniques to improve robustness, imperceptibility and security. These new techniques are as follow:

First, multi- intensity embedding technique is adopted in the embedding process. Because the intensity of watermark has different influences to wavelet coefficient in different resolution layer, so using different intensity in corresponding layer, we can gain the merit of stronger anti-attack ability and imperceptibility

Second, applying spread spectrum code to permute the original watermark so a new scrambling watermark is established. By reducing the effect of destroyed watermark image, the technique has the ability of anti-clipping, moreover, the technique improves the security of watermarking for needing scrawling password to extract the original watermark.

Third, interlaced watermark embedding technique is introduced. In this technique, we interlace several copies of watermark in different resolution to embed in wavelet transform domain. As a result the recovered watermark is shown better performance after various attacks.

6247-20, Poster Session

Jet noise analysis by Gabor spectrogram

Q. Xu, Nanjing Univ. of Science & Technology (China)

A research was conducted to determine the functions of a set of nozzle pairs. The aeroacoustical performance of these pairs can be used to analyze the deformation of structure and change of jet condition. The jet noise signal was measured by a microphone placed in the radiation field of jet flow. In addition to some traditional methods used for analyzing noise both in time and frequency domain, Gabor spectrogram is adopted to obtain the joint time-frequency pattern of the jet noise under different jet conditions from nozzles with different structures. The jet noise from three nozzle pairs worked under two types of working conditions is treated by Gabor spectrogram. One condition is both nozzles in the nozzle pair keep their structure at a fixed chamber pressure, while another condition is one of these two nozzles’ throat size decreases during the jet procedure under a fixed chamber pressure. Gabor spectrograms with different orders for the jet noise under the second condition are obtained and compared. Then a rational order is selected in analyzing the jet noise. Results are presented in this paper. The Gabor spectrogram patterns of these two conditions are with marked difference. The noise keeps its frequency peak during the whole jet procedure in the first condition. But there is a frequency peak shift in the second condition at a certain size of throat. The distribution of frequency peak along with the decrease of throat presents two states. This would be helpful for nozzle structure recognition.

6247-35, Poster Session

The joint time-frequency spectrogram structure of heptanes boilover noise

Q. Xu, Nanjing Univ. of Science & Technology (China)

An experiment was conducted to study the noise characteristics in the boilover phenomena. The boilover occurs in the combustion of a liquid fuel floating on water. It will cause a sharp increase in burning rate and external radiation. Explosive burning of the fuel would cause potential safety consequence. Combustion noise accompanies the development of fire and displays different characteristics in typical period. These characteristics can be used to predict the start time of boilover. The acoustic signal in boilover procedure during the combustion of heptanes-water mixture is obtained in a set of experiments. Joint time-frequency analysis (JTFA) method is applied in the treatment of noise data. Several JTFA algorithms were used in evaluation the , These algorithms include Gabor, adaptive spectrogram, cone shape distribution, choi-williams distribution, Wigner-Ville Distribution, and Short Time Fourier Transform with different windows such as rectangular, Blackman, Hamming and Hanning. Time-frequency distribution patterns of the combustion noise are obtained, and they are compared with others from jet flow and small plastic bubble blow up.

6247-36, Poster Session

An application of unsupervised learning artificial neural networks and dual-color spectrograms to predict the staging and recurrence rates of prostate cancer

K. A. Byrd, Howard Univ. and The George Washington Univ.; H. H. Szu, The George Washington Univ.

Introduction: Natural Intelligence (NI) has emerged as a very powerful new branch of science - its function: to simulate the unsupervised data fusion functions (in the sense of Dude & Hart unlabelled data classifier) of the human brain to solve various day-to-day problems via computers. AI resembles the human brain in terms of its architecture, design and functionality. It can be used to fuse sensory data without lookup table exemplars; and then by supervision to categorize the feature patterns and images by exemplars, construct decision trees to solve problems. There have been numerous applications of rule-based expert system AI in science, engineering, biology, medicine, and the financial market; this study focuses on the Biomedical applications. We go beyond AI without the biases of prior knowledge and adopt NI first developed by Szu in terms of the isothermal equilibrium brain and pairs of sensors. Purpose: The purpose of this investigation shall be to discuss the unsupervised learning Artificial Neural Networks using the dual color infrared spectrograms capturing the angiogenesis physiology effect in predicting staging and recurrence rates of prostate cancer in males. Pilot studies and well as experimental studies will be examined, in addition to possible combinations of traditional mathematical modeling methods along with Neural Networks. Expected Results: It is predicted that the most effective means of tackling this problem will involve Artificial Neural Networks in a complementary fashion with other techniques. This, we believe, will be the long-term role for Artificial Neural Networks in the medical field, especially in prostate cancer management.

6247-38, Poster Session

Smart hearing aid

N. Azizian, H. H. Szu, The George Washington Univ.

Hearing aids are small and miniature instruments, which help you to overcome your hearing loss. All the different types of aid require the basic parts of a microphone, amplifier, receiver and the batteries for their normal functioning. All these together with the controlling systems decide how the hearing aids work.

The inside mechanisms of hearing aids vary among devices, even if they are the same style. Three types of circuitry, or electronics, are used:

- Analog/Adjustable: The audiologist determines the volume and other specifications you need in your hearing aid, and then a laboratory builds the aid to meet those specifications. The audiologist retains some flexibility to make adjustments. This type of circuitry is generally the least expensive.
- Analog/Programmable: The audiologist uses a computer to program your hearing aid. The circuitry of analog/programmable hearing aids will accommodate more than one program or setting. If the aid is equipped with a remote control device, the wearer can change the program to accommodate a given listening environment. Analog/programmable circuitry can be used in all types of hearing aids.
- Digital/Programmable: The audiologist programs the hearing aid with a computer and can adjust the sound quality and response time on an individual basis. Digital hearing aids use a microphone, receiver, battery, and computer chip. Digital circuitry provides the most flexibility for the audiologist to make adjustments for the hearing aid. Digital circuitry can be used in all types of hearing aids and is typically the most expensive.

But the basic concept of how hearing aids works is the same. The microphone picks up sounds from the environment and sends them to a processor that amplifies the signal (makes it louder). The hearing aid will amplify some pitches of the incoming sound more than others depending upon your child's hearing loss. Your audiologist uses the hearing aid's tone controls (located on the reverse side of the instrument) to make the amplified sound appropriate for the person's hearing loss.

We propose the new hearing aid, which we call Smart Hearing Aid. The purpose of this paper is to discuss the process of enhancing dim target signals and reducing noises by unsupervised learning algorism. In addition, the Smart Hearing Aid is expected to enhance the pitches and sounds specific to the need of each individual.

6247-40, Poster Session

Biological vision system emulating pair of eyes

D. Schneider, Consultant

We propose a vision system which locates and tracks objects based on foveal vision, and which utilizes twin cameras to obtain better depth perception and higher localized resolution. The cameras will allow wide field-of-view surveillance with localized high resolution in areas of interest. 1 By making use of this concept of foveal vision, this vision system will reduce the data throughput bottleneck associated with image-processing. 2 Electro-optic sensors are using 1000 x 1000 arrays for multiple colors, instead of the typical single color 128 x 128 array. This increase in sensor size produces data rates which onboard processors are unable to handle. Our biological vision system avoids this hazard by incorporating small areas of higher resolution within a wide field of view having a lower resolution. 2

References

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6247-41, Poster Session

Biomimetic electronic prothesis

C. R. Nwabuebo, H. H. Szu, The George Washington Univ.

Biomimetic electronic prothesis for better sensing & processing. Review of early works on ears, eyes will be given. Recent advance in blind sources separation will be reviewed, and some of simple signal-to-noise fusion algorithm of pair of sensors will be implemented. Feature extraction and memory loading will be considered.

6247-44, Poster Session

Pairs of EFID's for secured applications

A. Mehmood, H. H. Szu, The George Washington Univ.

This paper presents a biomimetic of binaural smart sensors for the low-voltage low-power RFID correlation applications. This design utilizes a correlation pair of RFID for cheaper, faster, better application. The better is due to correlation provides a security codec and the natural avoidance of noise & other multiple path effects. Pair of RFID sensors also provides better security and in this paper we also studied that how RFID pair provides better security and privacy

6247-45, Poster Session

Authenticated, private, and secured smart cards

H. H. Szu, A. Mehmood, The George Washington Univ.

From the historical perspective, a better antenna, a low power circuitry and a new material, together made possible a miniature counter-measure against the Radar, a fake target return with Digital Reflection Frequency Modulation (DRFM). Such a military counter-measure have found its way in the commerce as a near field Radio Frequency Identification (RFID), a passive tag attached to every read-writable Smart Card (SC): Passports, medical or biometric ID, driver licenses, library ID at a fractional dollar cost and versatile than the optical bar-code scan. Despite of RFID popularity, the lacking of Authenticity, Privacy and Security (APS) protection restricted somewhat the wide spread commercial, financial, medical, legal and militarily applications. For examples, an affordable APS practice on erasable tags is to obfuscate a passkey, say a private number K, by another randomized tag number T, and a reader number R, i.e. T*K & R*K appeared on them, where * denotes invertible operation, e.g. EXOR. Then, only the authentic owner who knew all can interrogate by an inverse operation, e.g. EXOR*EXOR= I. However, such a pseudo-asymmetric RSA codec was easily compromised by a hacker seeking exhaustively frequent words interpretation. Knowing Radar history, we had countered the counter-measure DRFM based on instead one RFID tag per SD, two tags holding either the head or the tail portion of the ID readable by different modes of the interrogator. We adopt a hardware-software hybrid approach: if you don't get it, you can't hack it. According to Radar, we can choose the amplitude, the frequency, the phase, the polarization, and two radiation energy supply principles, the capacitance coupling (~6m) and the inductance coupling (<1m), to code the pair of tags differently. A casual skimmer equipped with single-mode reader can not read all. We consider near-field and far-field applications in this paper. The near-field is at check-out counters or the convey-belt inventory involving sensitive and invariant data. The far-field is to identify the item and also know its location passively. If more power for long distance of propagation becomes cheaper in the near future, then a triangulation with pair of secured readers, located at known geo-locations, could interrogate and identify items or persons and their locations in a GPS-blind environment.

Conference 6248: Wireless Sensing and Processing

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6248-100, Plenary Presentation

Optimal polarized waveform design for low-grazing-angle targets in compound-Gaussian clutter

A. Nehorai, Washington Univ. in St. Louis

Targets at low elevation angles over the sea surface, such as sea-skimming missiles, are known to be difficult to detect due to the strong coherent multipath interference and non-Gaussian sea clutter. We develop optimal design methods of polarimetric radar signals to improve the sensing performance of such targets. The polarized waveforms are optimally selected based on the target and clutter parameters. We use a weighted sum of the Cramer-Rao bounds on the parameters of interest as the optimization cost function. We compare the performances of different sensor systems, including arrays of 6D and 2D vector sensors and 1D uniformly polarized sensors. Simulation examples illustrate the performance of the proposed methods for target detection and estimation.

This work has been done in collaboration with Martin Hurtado and Jian Wang.

6248-01, Session 1

Design and implementation of a MIMO MAC protocol for ad hoc networking

J. Redi, W. Watson, R. Ramanathan, P. Basu, F. Tchakountio, BBN Technologies; M. Girone, Lucent Technologies

Multiple Input Multiple Output (MIMO) provides the potential for significant gains in channel capacity and spectral efficiency through its use of multiple element antenna systems and space-time coding. There are numerous published accounts of experimental MIMO communications links with high numbers of transmit and receive antennas, as well as commercial products exploiting MIMO with smaller antenna configurations. However, the use of MIMO as a modulation scheme for mobile ad hoc networking has so far only been explored as part of a theoretic or simulation exercise. In this paper we describe the design and implementation of a MAC protocol for a MIMO system which is designed to exploit the capability of 8x10 MIMO for ad hoc networks. This work is unique in that from the start our design considered the specific capabilities and parameters of an existing 8x10 MIMO physical layer, including significant decoding delays, variable array size and coding schemes, as well as fixed frame sizes. Furthermore, given the bandwidths and antenna array sizes available, the physical layer design could achieve hundreds of megabits in link capacity, and our MAC protocol therefore needed to be designed and implemented in such a way as to maximize this capacity, particularly in a network multi-hop environment. Our MIMO MAC protocol provides this capability while supporting multi-hop ad hoc networks through novel schemes for channel access, segmentation/reassembly, ARQ and link adaptation. This paper discusses the challenges and tradeoffs involved in developing a MAC for real MIMO hardware, and briefly describes a subset of our solutions to them.

6248-02, Session 1

Implementation and field demonstration of PacketBLAST system for tactical communications

A. Pidwerbetsky, M. J. Beacken, Lucent Technologies

A recent breakthrough in wireless communications, Multiple Input Multiple Output (MIMO) radios, vastly expands the capacity and connectivity of communications for forces operating in challenging environments such as urban or forested terrain.

A MIMO architecture called BLAST (Bell Laboratories Layered Space-Time) has been formulated to realize these capacities. For battlefield applications BLAST would vastly expand the data rate capacity achievable within the military frequency bands and so enable substantial improvements in situational awareness, accelerating the availability, accuracy, and timeliness of critical communications. This is particularly critical given the dramatically increasing data rate requirements and limited spectrum allocations for tactical communications. We have developed a packet version of BLAST, called PacketBLAST specifically to support high mobility, ad-hoc, tactical communications on the move in challenging environments.

PacketBLAST offers multiple benefits in achieving assured high data rate communications: high data rate communications in non-LOS (line-of-sight) links and limited bandwidths, lower probability of detection (LPD), improved anti-jam (AJ) performance, coherent gain from multi-element array (even in strongly scattered environments) fast, fine scale adaptation to changes in electromagnetic field, antenna or system and inherent protection against untrained interceptors.

We have implemented a spread spectrum (with 21 dB of processing gain), 8 transmitter by 10 receiver PacketBLAST system and have tested it in a number of field demonstrations. The field demonstrations have shown high data rate communications in both line-of-sight and non-line-of-sight environments. This high data rate has been shown in highly mobile communications-on-the-move in challenging environments.

This abstract is being submitted to Ananthram's session on MNM (Mobile Network MIMO).

6248-03, Session 1

MNM channel characterization

J. Ling, D. Chizhik, Bell Labs.

The Defense Advanced Research Projects Agency has instituted a program called Mobile Network MIMO to demonstrate a real-time, mobile, peer to peer, ad-hoc networked MIMO system in a realistic tactical environment. The performance of the ad-hoc network is fundamentally limited by the communications channel. The wireless channel is notoriously difficult, yet still important to characterize. A key propagation question addressed here is whether the channels offer enough scattering richness to benefit from MIMO systems in rural environments ranging from densely wooded to open field with large but sparse clutter within Line of Sight. Results from extensive channel measurements taken at the Lakehurst Navel Air Engineering Station are reported.

6248-04, Session 1

Mobile MIMO testbeds and demonstration

A. Gummalla, H. Lee, San Diego Research Ctr., Inc.

Multiple Input - Multiple Output (MIMO) is a new communications paradigm which brings significant benefits to future communication systems. In contrast to conventional wireless communication systems, MIMO systems exploit the spatial diversity available in multipath propagation to create parallel channels within a common bandwidth. The multiple channels can be used for capacity enhancement, coverage improvement, lower radiated power spectral density, interference/jammer suppression, multi-beam communication and battery power savings. Tactical and military communication systems have significantly different imperatives than commercial research. Mobility, operation in hostile environments, low probability of detection, distributed MANET operation in diverse scenarios (desert, forests, urban and sub-urban) are important requirements for tactical radios.

Research, development and exploitation of MIMO technology for tactical communication systems is significantly limited due to the lack of good testbeds to verify and validate theoretical work.

The team of San Diego Research Center (SDRC) and Brigham Young University (BYU) has built and demonstrated mobile testbeds that enable rapid algorithm development and performance assessment in real world scenarios. Using these testbeds, we have successfully demonstrated the feasibility of Mobile MIMO by closing 1000m links, at 50 mph speeds, at 8 bps/Hz spectral efficiency. This work has enabled SDRC to gain an in-depth understanding of the MIMO opportunity for military applications. In this paper we will describe the Mobile testbed design, Mobile MIMO drive test results and streaming video demonstration results.

6248-05, Session 1

Link scheduling media access protocol for mobile MIMO ad hoc networks

A. Gummalla, G. Nallamothu, San Diego Research Ctr., Inc.

Multiple Input - Multiple Output (MIMO) is a new communications paradigm which brings significant benefits to future communication systems in terms of capacity enhancement, coverage improvement, lower radiated power spectral density, interference/jammer suppression, multi-beam communication and battery power savings. Most advances in MIMO focus on algorithms that to improve point-to-point link performance in a static and interference free scenario. Networked operation creates highly dynamic scenarios that can leverage the many degrees of freedom of MIMO systems. These networks are optimized based on operating environments and application mission. For instance, in a multipath rich environment, Spatial Multiplexing (SM) is selected for high throughput, whereas, in the less rich multipath case, Space-Time Codes (STC) are used for robust communication to mitigate jamming signals as well. In LOS scenarios, beamforming (BF) techniques are applies to increase range and avoid interference. SM, STC, BM, and other smart antenna approaches call for an adaptive and opportunistic Media Access Control (MAC), which can optimize network performance across diverse scenarios. As a result, "military" systems equipped with such MAC are capable of withstanding harsh tactical and enemy obstruction while optimizing network performance instead of point-to-point solutions that provide high-throughput MIMO benefits only under favorable conditions.

SDRC designed and simulated a Media Access Control (MAC) protocol that maximizes the network benefit of MIMO systems. SDRC's MIMO MAC schedules links dynamically based on interference, traffic and channel characteristics. In this paper we discuss the challenges of networking mobile nodes with MIMO capabilities and propose a media access protocol that takes advantage of MIMO degrees of freedom. We present simulation results that demonstrate significant improvement in network performance in scenarios envisioned for FCS (Lakehurst scenario).

6248-06, Session 2

On the estimation of the movement direction of RF tagged items

M. G. Amin, J. Wang, Villanova Univ.

Radio Frequency Identification (RFID) has recently attracted much attention in both the technical and business communities. It has several applications, such as access control, localization tracking, real-time monitor, and object identification. Situations may arise where the movement directions of the tagged RFID items through a portal are of interest and must be known. Doppler-based direction estimation may prove difficult to perform by RFID readers. Several alternative approaches, including the use of an array of sensors with arbitrary geometry, can be used. In this paper, we consider direction of arrivals (DOA) estimation techniques for application to near-field narrowband Radio Frequency Identification (RFID). Particularly, we examine the use of a pair of RFID antennas to track the moving RFID tagged items through a portal. With two antennas, the near-field case simplifies to a far-field problem yielding a simple way for identifying the direction of the tag movement, where only one parameter, the angle, needs to be considered. We also examine the effects of the antenna patterns on DOA estimation. The latter is performed using the root Multiple Signal Classification (MUSIC) method. It is shown that tracking of the moving direction of the tag simply amounts to computing the spatial cross-correlation between the data samples received at the two antennas. Indoor experiments are conducted in both the Radar Imaging and RFID Labs at Villanova University for validating the proposed target movement direction technique.

6248-07, Session 2

Theory and experiments on Peano and Hilbert curve RFID tags

J. McVay, A. Hoorfar, Villanova Univ.; N. Engheta, Univ. of Pennsylvania

Recently, there has been considerable interest in the area of Radio Frequency Identification (RFID) and Radio Frequency Tagging (RFTAG). This emerging area of interest can be applied for inventory control (commercial) as well as friend/foe identification (military) to name but a few. The current technology can be broken down into two main groups, namely passive and active RFTAG's. Utilization of Space-Filling Curve (SFC) geometries, such as the Peano and Hilbert curves, has been recently investigated for use in completely passive RFID applications In this work, we give an overview of the space-filling curves and the potential for utilizing the electrically small, resonant characteristics of these curves for use in RFID technologies with an emphasis on the challenging issues involved when attempting to tag conductive objects. In particular, we investigate the possible use of these tags in conjunction with high impedance groundplanes made of Hibert or Peano curve inclusions to develop electrically small RFTAGs that may also radiate efficiently, within close proximity of large conductive objects.

6248-08, Session 2

RFID-assisted localization and tracking

Y. Zhang, M. G. Amin, Villanova Univ.

Radio frequency identification (RFID) is poised for growth as businesses and governments explore applications implementing RFID. The RFID technology will continue to evolve as a response of new demands for human and target location and tracking. This paper deals with two-dimensional (2-D) localization of targets of interest by using multiple reader antennas and signal returns from RFID tags. Targets of interest can be either in a static environment mode or mobile with a constant-speed movement. Various indoor experiments are conducted in the RFID Lab at Villanova University to examine the applicability of target localization methods based on time difference of arrival (TDOA) and radio signal strength information (RSSI), applied separately or combined. RFID tags with known positions are used to calibrate the TDOA and RSSI estimation methods. Target localization accuracy can then be enhanced through proper weighted averaging. We consider the case of line-of-sight (LOS) between the readers and the tags, and the more challenging case of non-line-of-sight (non-LOS). A multi-port signal analyzers, rather than actual RFID readers, are used in the experiment to provide detailed information on the collected data measurements. Robustness and sensitivity of the proposed methods to errors in both the time difference and the signal strength of signal arrivals are examined and used to reflect on practical RFID reader implementations. Preliminary analysis of the proposed methods shows good localization and tracking performance.

6248-09, Session 3

Multirate RZ communications for dispersive wireless optical channels

B. Y. Hamzeh, M. Kavehrad, The Pennsylvania State Univ.

Wireless optical communications is one of the most promising candidates for future broadband communications, offering transmission rates far

beyond possible by RF technology. Free Space Optical Communication through cloud-obscured channels suffers from severe degradations due to multi-scattering, which induces delay spread in the received signal. The delay spread of FSO channel can vary considerably according to channel conditions, varying from nanoseconds to microseconds under clear and cloudy channel conditions, respectively. These changes can occur gradually as in the case of a cloud overcast clearing off, or abruptly as in the case of scattered clouds.

In order to maximize channel throughput, powerful modulation schemes need to be employed and provide reliable communications. Multi-rate communications using fractal modulation has received wide attention in the research community, as an efficient mean to provide reliable communications. Additionally, optimum pulse shaping has been shown to be a crucial element in optimizing system performance.

In this paper, we present a new approach to wireless optical communications, where we combine multi-rate communications with short-pulsed RZ modulation. We show that multi-rate communications provide diversity against channel degradation and fluctuation, while RZ modulation is more robust to dispersive channel effects in comparison to NRZ modulation, thus providing an overall improvement in system performance, reliability and availability.

6248-10, Session 3

Space-time-frequency block codes for LPD applications

H. Lee, A. Gummalla, San Diego Research Ctr., Inc.

Multiple Input - Multiple Output (MIMO) is a new communications paradigm which brings significant benefits to future communication systems in terms of capacity enhancement, coverage improvement, lower radiated power spectral density, interference/jammer suppression, multi-beam communication and battery power savings. Despite the significant potential, little work has been done to exploit MIMO technology for tactical and military applications. Tactical and military communication systems have significantly different imperatives than commercial research. Mobility, operation in hostile environments, low probability of detection, distributed MANET operation in diverse scenarios (desert, forests, urban and sub-urban) are important requirements for tactical radios. Most research in commercial space falls far short of meeting these objectives.

Space-Time Codes (STC) operate by introducing spatial and temporal redundancy into communications by repeating information bearing symbols over multiple antennas in multiple time slots. These techniques are ideal for LPD/AJ applications. They are robust against channel estimation errors due to mobility or low SNR. We have enhanced Orthogonal Space-Time Block Codes (OSTBC) through spectral pre-coding. Spectral pre-coding operates by spreading the input QAM symbols across all sub-carriers via a fast unitary transformation. On the receive side, a corresponding de-spreading operation is performed. This results in a new class of orthogonal space-time-frequency block codes (OSTFBC) that provide improved performance in wide-band settings. Simulation results show OSTFBC out-performs conventional SISO systems by a substantial margin, and out-performs OSTBC by ~ 3 dB. It is shown that properly designed STC techniques can transmit signals with 10-15 dB lower power spectral density for similar BER performance.

6248-11, Session 4

Wireless LAN signal strength in a 3-story cinderblock building

B. B. Luu, R. D. Gopaul, Army Research Lab.

The U.S. Army Research Laboratory, in support of network communications for a Horizontal Fusion program in 2003, experimented with large-scale wireless LANs at the McKenna facility in Fort Benning, GA. In total, we deployed two wireless LANs, one consisting of both the 802.11A and 802.11G protocols and the other consisting of only the 802.11G protocol. In this paper, we will describe the deployment of wireless LAN access points and show the mapping of wireless LAN signal strength reception in rooms of building B1 of McKenna village at Fort Benning, GA. We will also describe our observations in using these wireless LANs.

6248-13, Session 5

Energy-efficient false data detection in wireless sensor networks

S. Ozdemir, Arizona State Univ.

Wireless sensor networks provide economical and viable solutions to many monitoring problems.

The practical deployment of sensor networks, however, introduces problems that traditional networks do not face. One such problem is node compromise attacks in which intruders physically capture sensor nodes and harm the network by injecting false data. False data injection attacks may deceive the base station and/or deplete the limited energy resources of relaying sensor nodes. Traditional authentication schemes cannot prevent these attacks if there exists one or more compromised node in the network. To this end, this paper proposes a security protocol that detects false data injection attacks using a collaborative authentication technique. The proposed protocol detects and eliminates false data by constructing consecutive Merkle Hash Trees (MHT) on the path from the cluster head to the base station. As opposed to previous techniques against false data injection, the proposed protocol provides secure data aggregation during data transmission. The performance evaluation results show that, considering the security it provides, the proposed protocol is energy efficient compared to previous false data detection techniques.

6248-14, Session 5

Mesh networked unattended ground sensors

W. Calcutt, B. Jones, R. S. Fish, M. A. Winston, McQ Associates, Inc.; J. G. Houser, Army Research Lab.

McQ has introduced a family of low cost unattended ground sensors that utilize ad hoc, mesh network communications for wireless sensing. Intended for use in an urban environment, the area monitored by the sensor system poses a communication challenge. A discussion into the sensor's communication performance and how it affects sensor installation and the operation of the system once deployed is provided.

6248-15, Session 5

Jamming attack detection and countermeasures in wireless sensor network

R. S. Muraleedharan-Sreekumaridevi, L. A. Osadciw, Syracuse Univ.

Real-world sensor network applications such as military, environmental and health monitoring necessitate communication security. Due to the limited resource constraints in wireless network security (WSN), security in protocols is sacrificed or kept at minimal. Unfortunately, traditional network security schemes cannot be used directly in WSN. Hence a trade-off between security and resource constraints remain a dilemma. In this paper, an extension to the security of physical layer of a predictive sensor network model using the ant system is proposed.

The ant system, a learning algorithm, possesses unique features that keep the network functional by detecting weak links and re-routing the agents. The orthogonal communication parameters controls the decisions made by the ant system. The agents carry updated information of its previous nodes, which help in monitoring and management.

Denial of Service (DoS) attacks on sensor networks not only diminishes the network performance but also reduces the integrity and reliability of the information. Detection of a DoS threat is more crucial than recovering from the attack. Hence in this paper a novel approach in detecting the DoS attack is discussed by formulating a hypothesis. The DoS attack is dependent on the vulnerabilities in each layer. In this paper, the physical layer DoS attack is analyzed and a defense mechanism is proposed. Clas-

sification of the jammer under various attacks on the sensor nodes is formulated using receiver operating characteristics (ROC). This approach helps achieving a maximum reliability on DoS claims improving the Quality of Service (QoS) in WSN.

Integrity and confidentiality of the sensitive information being communicated across WSN made of RF communication links is very crucial. A sensor network is not only affected by harsh environment and intelligent threats attempting to compromise the WSN. Implementation of this algorithm can handle many DoS jamming attempts to compromise the nodes should never be possible and yet maintain the integrity and confidentiality of information. The WSN's performance is evaluated based on accuracy and the response time in detecting and recovering from the jamming attack. This process of detection a DoS-jammer attack can also be extended to other DoS attacks.

6248-16, Session 5

Toward in-band self-organization in energy efficient MAC protocols for sensor networks

S. Biswas, F. Yu, Michigan State Univ.

This paper will present a distributed TDMA scheduling protocol ISOMAC (In-band Self-Organized MAC) for energy-constrained sensor networks. The key idea in ISOMAC is to use an in-band signaling mechanism for MAC self-organization. Instead of sending explicit control packets as in existing sensor MAC protocols, nodes running ISOMAC use a bitmap vector in each data packet header for exchanging TDMA slot occupancy information among the neighbors. In the header of each outgoing packet, its transmitting node inserts a bitmap vector which represents the relative TDMA slot timing of all its neighbors with respect to the transmitting node's own slot location. As a newly joined node receives data packets from its neighbors, it gradually learns about the TDMA slot locations of all its neighbors and the neighbors' neighbors. Based on this allocation information up to two-hop neighbors, the new node is able to select a collision-free TDMA slot. In addition to its energy efficiency, ISOMAC has the following features: a) since it uses an in-band technique without any contention based operations, the protocol is virtually collision free; b) ISOMAC can be implemented without network time synchronization. c) The protocol is fair in guaranteeing certain data rate to each sensor node; d) finally, ISOMAC is remarkably insensitive to channel errors, which is unusual for an in-band protocol. ISOMAC's applications will include a wide range of network-centric systems such as unmanned ground sensor networks and self-organizing unmanned vehicle and robotic networks. We will report ISOMAC's protocol details and performance characterization in this paper.

6248-17, Session 5

Performance analysis of four routing protocols in sensor networks

A. Bellaachia, N. Weerasinghe, The George Washington Univ.

The efficiency of sensor networks strongly depends on the routing protocol used.

In this paper, we analyze four different types of routing protocols: LEACH, PEGASIS, HIT-M, and DIRECT. DIRECT routing protocol is one where all the sensing nodes directly send its information to the base station. LEACH sends data directly to the cluster head and the cluster head is in charge of sending them to the base station. PEGASIS is similar to LEACH but the nodes transmit through other nodes that are closer to the base station, rather than directly transmitting to the cluster head like LEACH does. HIT-M is hybrid of LEACH and PEGASIS, using the chain like structure used in PEGASIS to reduce energy costs and using TDMA (Time Division Multiple Access) computed on each individual node to increase parallelism of data transfer.

Sensor networks were simulated using TOSSIM simulator.

Several experiments were conducted to analyze the performance of these protocols including the power consumption and overall network performance. The experimental results show that HIT-M outperforms all other protocols while PEGASIS has better performance than LEACH and DIRECT. LEACH and DIRECT have similar performance. This paper also shows the power consumption for all protocols. On the average, DIRECT has the worst power consumption.

6248-18, Session 5

Clustering-based localization for wireless sensor networks

M. Medidi, R. Slaaen, S. R. Medidi, Washington State Univ.

Various applications, such as location-aided routing, in wireless sensor networks require knowing the relative or actual position of the sensor nodes. To address this need, recently, several localization algorithms to identify the node positioning in the sensor network have been proposed. In this paper, we propose another type of localization algorithm based on clustering to reduce the computational complexity and hence obtain a scalable solution. We present simulation studies under both regular and irregular topologies and varying connectivity to compare and evaluate position estimation errors and the message complexity.

6248-19, Session 6

Effects of code rate, data rate, and channel estimation on OFDM and OFDM-CDMA waveforms

J. W. Nieto, Harris Corp.

OFDM and OFDM-CDMA are competing multi-carrier waveform design approaches which can be used to send digital information over multipath/fading channels. Previous research has shown that each waveform can provide better performance than the other depending on the modulation used, the FEC code rate, and the channel characteristics under test. This paper will try to quantify these performance differences on various HF multipath/fading channels.

6248-20, Session 6

Performance of asynchronous multi-user MIMO OFDM systems

H. Jung, M. D. Zoltowski, Purdue Univ.

This paper investigates the performance of orthogonal frequency division multiplexing (OFDM) based multiple input multiple output (MIMO) multiple access channels with random timing delay. An asynchronous mode of data transmission is natural in the reverse link multi-user MIMO channel due to different locations among different users. Although optimal transmission algorithms for multi-user MIMO systems have been proposed to maximize the sum capacity, in practice, user cooperation exploiting other users' channel state information is not feasible in the multiple access channel. Thus, we evaluate the performance of various suboptimal transmitter diversity techniques such as space-time block coding, beamforming, and precoded space-time block coding over the asynchronous channel assuming that space-time minimum mean squared error (MMSE) receivers are used for asynchronous interference suppression. The average signal-to-interference and noise ratio resulting from MMSE combining indicates that the bit-error rate of space-time block coded multi-user OFDM is highly dependent on the amount of timing offset. Overall, simulation results demonstrate that closed-loop MIMO systems, which use only part of existing spatial subchannels, need to be employed to obtain substantial diversity gains in asynchronous multi-user OFDM channels.

6248-21, Session 6

Mobile infostation network technology

G. S. Rajappan, Mayflower Communications Company, Inc; J. Acharya, H. Liu, N. Mandayam, I. Seskar, R. Yates, Rutgers Univ.; R. Ulman, U.S. Army Research Office

Inefficient use of network resources on the battlefield is a serious liability: if an asset communicates with the central command for data-a terrain map, for instance-it ties up the end-to-end network resources; when many such assets contend for data simultaneously, traffic is limited by the slowest link along the path from the central command to the asset. A better approach is for a local server, known as an Infostation, to download data on an anticipated-need basis when the network load is low. The Infostation can then dump data when needed to the assets over a high-speed wireless connection. The Infostation serves the local assets over an OFDM-based wireless data link that has MIMO enhancements for high data rate and robustness. We aim for data rate in excess of 100 Mbps, spectral efficiency in excess of 5 bits/sec/Hz, and robustness to poor channel conditions and jammers. In order to achieve these goals under the anticipated channel conditions, we propose an adaptive physical layer that determines power levels, modulation schemes, and the MIMO enhancements to use based on the channel state and the level of interference in the system. We incorporate MIMO enhancements such as spatial multiplexing, beamforming, and diversity. We also incorporate the idea of a super-user: a user who is allowed preferential use of the high data rate link. We propose a MAC that allows for this priority-based bandwidth allocation scheme. The proposed Infostation MAC is integrated tightly with the physical layer through a cross-layer design.

6248-22, Session 6

Distributed MIMO-OFDM in imperfectly synchronized cooperative network

Y. Zhang, G. Wang, M. G. Amin, Villanova Univ.

Coded space-time cooperation is an efficient approach in delivering information over a relay network, particularly when the channels experience fading. Multiple spatially distributed transmit and receive terminals form a distributed multiple-input-multiple-output (MIMO) systems, thus providing high data rates and high diversity gains. However, unlike conventional co-located MIMO systems, it is impractical for distributed MIMO networks to maintain a perfect synchronization between different transmit terminals. In the presence of even a fractional-symbol delay between the signals transmitted from different terminals, the channels may become highly dispersive although the channels are physically memoryless. Existing methods solve such problem based on time-domain approaches where adaptive equalization is required at the receivers for combining the information transmitted from distributed sources. Such schemes are often too complicated, and are particularly impractical to be applied in relay terminals. In this paper, we propose the use of OFDM-based approaches using distributed space-frequency codes. The proposed schemes are insensitive to fractional-symbol delays and lead to higher data rate transmission and simplified implementations. In addition, the proposed schemes permit the use of relatively simple amplify-and-forward algorithm in multi-hop wireless networks without delay accumulations. The proposed methods remove the time delay in each relaying hop by reconstructing the prefix and, as such, improve the spectral efficiency, while keeping a simplified relaying structure.

6248-23, Session 6

OFDM custom instruction set NIOS-based processor for FPGAs

U. H. Meyer-Bäse, D. Sunkara, Florida State Univ.; E. Castillo, A. Garcia, Univ. de Granada (Spain)

Orthogonal frequency division multiplexing (OFDM) spread spectrum techniques, sometimes also called multi-carrier or discrete multi-tone modulation, are used in bandwidth-efficient communication systems in the presence of channel distortion. The benefits of OFDM are high spectral efficiency, resiliency to RF interference, and lower multi-path distortion. OFDM is the basis for the European digital audio broadcasting (DAB) standard, the global asymmetric digital subscriber line (ADSL) standard, in the IEEE 802.11 5.8 GHz band standard, and ongoing development in wireless local area networks.

The modulator and demodulator in an OFDM system can be implemented by use of a parallel bank of filters based on the discrete Fourier transform (DFT), in case the number of subchannels is large (e.g. K\>25), the OFDM system are efficiently implemented by use of the fast Fourier transform (FFT) to compute the DFT. We have developed a custom FPGA-based Altera NIOS system to increase the performance, programmability, and low power in mobil wireless systems.

Nios Embedded processors supplied by Altera Corporation provide a powerful, robust platform for developing and implementing complex algorithms. With over 10K systems sold to more than 3K customers, Nios processors had been a great success in recent years.

The unique custom instruction feature of Nios processors was used to enhance the performance of OFDM system dramatically. This unique feature involves implementing a part or entire algorithm in hardware and making it accessible to software through specially generated software macros known as custom instructions. In this paper we discuss the custom design of decimation-in-frequency radix-2 FFT used for OFDM modulation and demodulation. The performance enhancement of the custom implementation of this algorithm is then measured against software-only implementation with different system configurations.

6248-24, Session 7

New technique to combat multipath fading in wireless networks

G. W. Webb, Univ. of California/San Diego; I. V. Minin, O. V. Minin, Novosibirsk State Technical Univ. (Russia)

The mobile wireless networks of the future will be expected to carry high-rate digital video, voice and data in environments of “impressive diversity” from dense foliage to dense urban obstacles. Under these conditions, the phenomenon of multipath fading can occur. In multipath fading, a microwave antenna receives a signal from a transmitter that is a sum of the desired line-of-sight (LOS) signal and at least partially coherent non-line-of-sight (NLOS) signals. The NLOS signals arise from reflections off structures, terrain, etc. and from diffraction off obstacles. Under these conditions the LOS and NLOS signals can be received with nearly equal amplitude and nearly 180o out of phase from each other, producing severe destructive interference or multipath fading. We have, however, developed a technique to reduce multipath fading to arbitrarily small values. Our technique is based on a free parameter in the design of Fresnel zone plate antennas, a type of reference phase previously unrecognized1,2. We have established both experimentally and theoretically that the reference phase can be chosen to have non-standard values that shift the LOS beam phase linearly through 360o with only slight changes in antenna gain2,3. Of particular importance here is the new result that varying the reference phase does not shift the phase of NLOS signals entering the antenna from outside the main beam by an equivalent amount. Thus reference phase controls LOS beam phase preferentially over phase in NLOS directions allowing destructive interference and fading to be eliminated. Although we use a particular type of beam focusing antenna, namely a Fresnel zone plate antenna to demonstrate the effect, the technique is applicable to any type of focusing antenna where there is direct preferential control of LOS beam phase over NLOS directions. 1 I.V. Minin and O.V. Minin, “Control of focusing properties of diffraction elements” Sov. J. Quantum Electron. 20, 198 (1990). Also see O.V.Minin and I.V.Minin. Diffractional Optics of Millimetre Waves. - IOP Publisher, London, Sept. 2004, 394p 2 G.W. Webb, “New Variable for Fresnel Zone Plate Antennas,” Proc. 2003 Antenna Applications Symposium, Allerton Park, Monticello, IL, September 15-17, 2003 (http://www.ecs.umass.edu/ece/allerton/papers2003/) and arXiv:physics/0303002 28 Feb 2003. 3 I.V. Minin, O.V. Minin, and G.W. Webb, “Flat and conformal zone plate antennas with new capabilities “ to be published. in the Proc. 18th International Confer-

ence on Applied Electromagnetics, ICECom 2005, to be held in Dubrovnik, Croatia,, 12-14 October 2005.

6248-25, Session 7

Seamless and drastic internet optimization for wireless ad hoc and satellite links

M. I. Kazantzidis, Broadata Communications, Inc.

The use of Internet Protocol (IP) suite over satellite platforms is limited by the large propagation delays to reach their earth-distant position and the wireless nature of channel errors. Before they can provide an effective and commerciable service, IP protocols require proper augmentation and correction precisely due to long feedback loops, large number of in-transit packets, transmission errors, possibly asymmetric links and intermittent connectivity. By a careful collective look to current research literature, we identify that all IP problems in long delay wireless networks either stem from network measurement inefficiency or can be better overcome if accurate measurements were available. In this paper, we introduce a flexible middle-box IP performance enhancement solution that deals with the satellite WAN optimization problem without changes to senders and receivers. It accomplished an IP steady state improvement factor that corresponds to approximately optimal channel utilization by effectively changing TCP/IP parameters according to innovative, accurate passive network measurements, suitable for the high bandwidth and delay wireless environment. We believe that our approach can optimize not only protocols but also improve currently proposed optimizations as those suggested in the SCPS transport. While this study is focusing on TCP, our concept can take on a wide number of transport, security, multimedia, real-time and QoS performance enhancements tasks.

6248-26, Session 7

Intelligent routing protocol for ad hoc wireless network

C. Peng, C. W. Chen, Florida Institute of Technology

A novel routing scheme for mobile ad hoc networks (MANETs), which combines hybrid and multipath-routing path properties with a distributed topology discovery route mechanism using control agents is proposed in this paper.

In recent years, a variety of hybrid routing protocols for Mobile Ad hoc wireless networks (MANETs) have been developed. Which is proactively maintains routing information for a local neighborhood (inter-cluster), while reactively acquiring routes to destinations beyond the global (intra-cluster). The hybrid protocol reduces routing discovery latency and the end-to-end delay by providing high connectivity without requiring much of the scarce network capacity. On the other side the hybrid routing protocols in MANETs likes Zone Routing Protocol still need route “re-discover” time when a route between zones link break. Sine the topology update information needs to be broadcast routing request on local zone. Due to this delay, the routing protocol may not be applicable for real-time data and multimedia communication.

We utilize the advantages of a clustering organization and multipath-routing path in routing protocol to achieve several goals at the same time. Firstly, IRP efficiently saves network bandwidth and reduces route reconstruction time when a routing path fails. The IRP protocol does not require global periodic routing advertisements, local control agents will automatically monitor and repair broke links. Secondly, it efficiently reduces congestion and traffic “bottlenecks” for Clusterheads in clustering network. Thirdly, it reduces significant overheads associated with maintaining clusters. Fourthly, it improves clusters stability due to dynamic topology changing frequently.

In this paper, we present the Intelligent Routing Protocol. First, we discuss the problem of routing in ad hoc networks and the motivation of IRP. We describe the hierarchical architecture of IRP, which consists of three protocols. We describe the routing process and illustrate it with an example. Further, we describe the control manage mechanisms, which are used to control active route and reduce the traffic amount in the route discovery procedure. Finial, the numerical experiments are given to show the effectiveness of IRP routing protocol.

6248-27, Session 7

Extended smart utilization medium access control (E-SUMAC) protocol for ad hoc wireless networks

J. Vashishtha, Colorado School of Mines; A. K. Sinha, PercepTek, Inc. and Carnegie Mellon Univ.

The demand of spontaneous setup of a wireless communication system has increased in recent years for areas like battlefield, disaster relief operations etc., where a pre-deployment of network infrastructure is difficult or unavailable. A mobile ad-hoc network (MANET) is a promising solution, but poses a lot of challenges for all the design layers, specifically medium access control (MAC) layer. Recent existing works have used the concepts of multi-channel and power control in designing MAC layer protocols. SUMAC developed by the same authors, efficiently uses the ‘available’ data and control bandwidth to send control information and results in increased throughput via decreasing contention on the control channel. However, SUMAC protocol was limited for single-hop, static ad-hoc network and also faced the busy-receiver node problem. We present the Extended SUMAC (E-SUMAC) protocol which works for multi-hop networks with mobile nodes. Also, we significantly improve the scheme of control information exchange in E- SUMAC to overcome the busy-receiver node problem and thus, further avoid the blockage of control channel for longer periods of time. A power control scheme is used as well to reduce interference and to effectively re-use the available bandwidth. Simulation results show that E-SUMAC protocol is promising for mobile, multi-hop ad-hoc network in terms of reduced contention at the control channel and improved throughput because of channel re-use. Results show a considerable increase in throughput compared to SU-MAC which could be attributed to increased accessibility of control channel and improved utilization of data channels due to superior control information exchange scheme.

6248-28, Session 7

Communications protocol for RF-based indoor wireless localization systems

T. Kasza, M. M. Shahsavari, V. Kepuska, M. Pinzone, Florida Institute of Technology

A novel application-specific communications scheme for RF-based indoor wireless localization networks is proposed. In such a system wireless badges, attached to people or objects, report positions to wireless router units. Routers are responsible for propagating collected badge information hop-by-hop toward one central unit of the system. Badges have very limited communication, energy, as well as processing capabilities. However, routers are significantly less constrained by battery than badges.

Each unit has one ISM 900MHz-band transceiver antenna and is able to synchronize its schedule by listening to other units’ periodic reference signals. Additionally, each unit can radiate a special sequence of bits at selected frequencies, so that any router in the wireless neighborhood can sense, store, aggregate and forward Received Signal Strength Indicator (RSSI) information. The more routers collect RSSI data of a particular unit, the more accurate the localization becomes. This data collection requirement makes the local communication unique and calls for application-specific protocol solutions. Once the central unit receives RSSI from routers, it calculates the overall relative positions of each unit in the system.

The goal of the presented research is to meet both the data collection and the routing requirements and develop a robust application-specific communication protocol for badges, routers and the central unit with maximum reliability, adaptability and flexibility. The new scheme has been developed based on Chipcon CC1010 Evaluation Module with limited

communication capabilities.

In the proposed system the mixed use of TDMA (Time Division Multiple Access) and FDMA (Frequency Division Multiple Access) techniques was necessary since local (badge-router) and inter-router communications must be separated to minimize collisions. Total amount of data to be transferred is expected to be relatively small. For satisfying the application-specific priorities of high-level reliability each packet has to be positively acknowledged.

Implemented badge-router and inter-router communication protocol rules show that the scalability of numerous system parameters can handle normal operations as well as an acceptable reaction level to emergency situations. The feasibility of the proposed protocol in a typical floor - 2-dimensional topology where routers are deployed in a grid fashion, is simulated. Results show that assuming normal operation and the maximum of 1000 badges, the system can periodically report in about every 5 seconds. Different scenarios are compared and the proposed scheme is demonstrated to meet the strict reliability requirements while providing energy-efficiency badges and an acceptable level of latency.

6248-29, Session 8

Evaluation of packet latency in single and multihop WiFi wireless networks

K. B. Anna, M. Bassiouni, Univ. of Central Florida

In this paper, we evaluate the packet latency performance of a new scheduler-based scheme that we have implemented on top of the p-persistent 802.11 MAC layer. We extended Cali's dynamic p-persistent 802.11 protocol from single class to multiple classes by means of a weighted fair queuing scheduler built on top of the MAC p-persistent layer. We used the ns2 simulator in the implementation and testing of our multiple-class scheduler and incorporated the scheduler-based architecture by modifying the ns2's 802.11 DCF implementation and the protocol stack of the wireless node. The scheduler is made part of the PriQueue class in ns2 and interacts with the MAC layer directly. Our tests showed that AEDCF cannot maintain the same throughput differentiation ratios among different traffic classes under different loads. In contrast, the p-persistent Scheduler scheme maintains the desired throughput differentiation ratios under different loads, gives higher total network throughput and provides easier tuning. We present detailed performance results of the scheduler-based architecture in terms of QoS differentiation and packet latency. All tests were implemented in ns2. The first part of the paper concentrates on single hop wireless networks and compares the scheduler-based scheme with AEDCF. The second part of the paper extends the evaluation to multihop wireless networks and examines the roles of the routing layer and the MAC layer. The routing layer adds some overhead in terms of route discovery, route maintenance, and packet delivery while the MAC layer adds the overhead of packet collisions and retransmissions.

6248-30, Session 8

Estimating degree of mixing in statistically multiplexed data

R. Narasimha, Georgia Institute of Technology; R. M. Rao, S. A. Dianat, Rochester Institute of Technology

This paper examines the problem of determining the degree of mixing of two independent and different types of traffic streams from observations of their statistically multiplexed stream. A common example of a pair of such different stream types in networks would be one conforming to the conventional Poisson model and the other obeying long-range dependence characterized by a heavy-tailed distribution. We provide an expression for the probability density function of the inter-arrival time of the mixed stream in terms of those of the input streams for the general case. An approach is provided to estimate input parameters from the first and second order statistics of the output traffic for the specific case of multiplexing Poisson and heavy-tailed processes.

6248-31, Session 9

GPS noncoherent early-minus-late power discriminator tracking performance in multipath environment

L. Liu, M. G. Amin, Villanova Univ.

Multipaths of the GPS signal reaching lead to undesirable tracking errors and inaccurate range and position information. In this paper, we consider the multipath effect on noncoherent early-minus-late power discriminator. Analytical treatment of the effect of the carrier phase offset of the multipath relative to the direct path on GPS receiver performance is provided. Compared with the well-known coherent discriminator, the noncoherent discriminator presents different tracking accuracy and sensitivity to multipath delay, magnitude and phase. The paper considers the front-end precorrelation filter, which is typically applied to remove out-of-band interference and noise. Selection of narrow precorrelation filter bandwidth can mitigate the multipath impeding effect on delay lock loop (DLL) and receiver discriminators. Computer simulations of the impact of the GPS multipath signal on the discriminator tracking performance are provided and shown to validate the corresponding analytical expressions. It is assumed that the early and late correlations are performed within the same navigation symbol, and no symbol transitions are encountered over the correlation interval.

6248-32, Session 9

Indoor wireless source localization based on area constraints

F. Ahmad, M. G. Amin, M. Shoeb, Villanova Univ.

The use of distributed sensor networks for monitoring an area, including detecting, localizing, and tracking one or more objects, is an emerging area of interest in a variety of military and commercial applications. Localization mainly requires accurate time-of-arrival (ToA) or angle-of-arrival (AoA) measurements at three or more sensors, located at known positions. Indoor environment renders localization a difficult problem because of non-line-of-sight (NLOS) propagation, clutter, and multipath clustering. Constrained hybrid localization schemes that employ both ToA and AoA information for improved source localization under NLOS conditions have been recently proposed. In this paper, we propose a general approach for indoor localization that utilizes additional constraints stemming from the indoor scene layout, and relies on apriori knowledge, such as the floor plan or the nature of the area being monitored. Some of these additional constraints may forbid or restrict the algorithm from searching for sources in pre-designated areas. Simulation and experimental results, comparing the performance of the proposed system with existing localization schemes, demonstrate improved performance using the proposed scheme.

6248-33, Session 9

IDMR beamforming in the presence of direction-independent array mainfold mismatch

E. L. Santos, M. D. Zoltowski, Purdue Univ.

The IDMR beamformer is based on a parametric estimate of the covariance matrix which is obtained using MUSIC to identify the location of the dominant sources and assuming that knowledge of the array manifold is available. In most applications, due to steering vector mismatch, the array manifold is not known precisely and the performance obtained via IDMR can be severally deteriorated. Steering vector mismatch is classified in two different types: direction-independent mismatch which equally affects signals arriving from different directions; and direction-dependent mismatch which affects signals arriving from different directions in different ways. The work presented in this paper is focused on a technique to enable the IDMR beamformer to operate in a scenario of direction-independent steering vector mismatch. In this paper it is proposed to use an

algorithm introduced by Friedlander to estimate the direction-independent steering vector mismatch. Friedlander's algorithm proposes to estimate the mismatch with the objective of forcing the signal steering vectors to be orthogonal to the noise subspace. In this paper the researchers show that only the steering vectors associated to the dominant signals should be used and that the algorithm fails to estimate the mismatch when non dominant signals are employed. Once an estimate of the mismatch is available, IDMR is then implemented accounting for the estimated steering vector mismatch. Simulation analysis show that this technique enables the IDMR beamformer to operate in a scenario of direction-independent manifold mismatch. In such a scenario the output SINR obtained with IDMR is substantially higher than the output SINR obtained with either the DMR or CG beamformers.

6248-34, Session 10

Study of wireless communication between MEMS sensor nodes

J. I. Rivera, Univ. of Central Florida and Alabama A&M Univ.; K. Heidary, M. Saafi, Alabama A&M Univ.

Wireless sensors networks are currently being used in different engineering fields such as civil, mechanical and aerospace engineering for damage detection. Each network contains approximately hundreds of MEMS sensors that communicate to the base station. These sensors are placed in different environments and locations that create changes in their output due to obstacles or interference between them and the base station. A thorough study has been conducted on distance communication, noise level and effect of environmental interferences. This paper involves the recreation of possible interference environments like magnetic fields created by electricity and cell phone communications; similarly an obstacle test such as cement and metal enclosures, outside and inside environments was tested. Also, the practice of classifying communication signals was studied in which the correct output could be obtained instead of an unknown. A neural network computer simulation was created in matlab that would learn what it would take to classify communication signals like time, amount of samples and overtraining. By gathering all this information it helps to save money and time in any application wireless MEMS sensors are used. Idealized models and pictures of communication paths have been created for easier explanation of results.

6248-35, Session 10

Near-Earth propagation of distributed sensors: problems and solutions

R. Wert, A. K. Goroch, E. Worthington, K. Chan, D. Tremper, L. Schuette, Naval Research Lab.

Both the military and consumer sectors are driving towards distributed networked sensors. A major stumbling block to deployment of these sensors will be the radio frequency (RF) propagation environment within a few wavelengths of the earth. Increasing transmit power (battery consumption) is not the practical solution to the problem. This paper will discuss some aspects of the near earth propagation (NEP) problem and provide a few solutions. When radiating near the earth the communications link is subjected to a list of physical impairments. On the list are the expected Fresnel region encroachment and multipath reflections along with the intriguing radiation pattern changes and near earth boundary layer perturbations. A significant amount of data has been collected on NEP. Disturbances in the NEP atmosphere have a time varying attenuation related to the time of day. Solutions, or workarounds, to the near earth propagation problem hinge on dynamic adaptive RF elements. Adaptive RF elements will allow the distributed sensor to direct energy, beam form, impedance correct, increase communication efficiency, and decrease battery consumption. Small electrically controllable elements are under development to enable antenna impedance matching in a dynamic environment. Additionally, small dynamic beam forming antennas will be developed to focus RF energy in the direction of need. By creating provisions for decreasing the output RF power to the level required, battery consumption can be reduced. With the addition of adaptive RF elements, distributed autonomous networked sensors can become a reality within a few centimeters of the earth.

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6249-38, Poster Session

Transmission of object-based fine-granular scalability video over wireless networks

X. Shi, Shanghai Univ. (China); G. Xiao, Shanghai Municipal Educational Examinations Authority (China); Z. Zhang, L. Shen, Z. Li, Shanghai Univ. (China)

It is a hot focus of current researches in video standards that how to transmit video streams over Internet and wireless networks. One of the key methods is FGS(Fine-Granular-Scalability), which can always adapt to the network bandwidth varying but with some sacrifice of coding efficiency, is supported by MPEG-4. Object-based video coding algorithm has been firstly included in MPEG-4 standard that can be applied in interactive video. However, the real time segmentation of VOP(video object plan) is difficult that limit the application of MPEG-4 standard in interactive video. H.264/AVC is the up-to-date video-coding standard, which enhance compression performance and provision a network-friendly video representation. In this paper, we proposed a new OBFGS (Object Based FGS) coding algorithm embedded in H.264/AVC that is different from that in mpeg-4. After the algorithms optimization and multi-media instruction-set optimization for the H.264 encoder, the FGS first finish the base-layer coding. Then extract moving VOP using the base-layer information of motion vectors and DCT coefficients. Sparse motion vector field of p-frame composed of 4*4 blocks, 4*8 blocks and 8*4 blocks in base-layer is interpolated. The DCT coefficient of I-frame is calculated by using information of spatial intra-prediction. After forward projecting each p-frame vector to the immediate adjoint I-frame, the method extracts moving VOPs (video object plan) using a recursion 4*4 block classification process. Only the blocks that belong to the moving VOP in 4*4 block-level accuracy is coded to produce enhancement-layer stream. Experimental results show that our proposed system can obtain high interested VOP quality at the cost of fewer coding efficiency under 3GPP /3GPP2 wireless common test conditions.

6249-01, Session 1

CBRN planning and response: collecting, analyzing, and using actionable knowledge

D. G. Angeley, M. D. Lockhart, General Dynamics Corp.

To save lives in a mass casualty event, decision makers need access to a wide range of information and analyses and they need direction on when and how to use that information. We have developed an integrated approach to support decision-making efforts within overwhelming CBRN events. The end product is called the Actionable Knowledge Report (AKR). This tool provides fused knowledge and analysis summaries focused on needs of specified end-users in a near-real time, web-based, multi-level secure, common operating picture environment.

The AKR provides to decision makers a tool to meet their overall goal of preserving and saving lives by breaking down their efforts into two broad areas: 1) minimizing casualties, and 2) managing the unavoidable casualties. To do this effectively, a number of capabilities in each of these areas must be considered (i.e. physical and medical protection, triage, decontamination, evacuation, treatment, and restriction of movement). To arrive at a solution, capabilities need to be connected into strategies to form a reasonable course of action (COA). To be successful, situational awareness must be maintained, and risks of implementation and sustainability of the execution must be taken into account. The AKR provides an interactive medium to develop and implement the best COA. Both the AKR and the underlying analytical process (including the incorporation of CBRN casualty and resource estimation tools) are described in this paper.

In addition, a CBRN situation can overwhelm the existing infrastructure and capabilities. This will place a large burden on the individuals, forcing them to explore alternative and non-conventional strategies. The AKR provides a mechanism by defining transition points or triggers that signal the onset of an overwhelmed situation, thereby providing an autonomous process to move away from more conventional doctrinal and unproductive approaches. This network-centric, autonomous enabling approach (including fusion from disparate sources and algorithmic approaches to automatically set trigger thresholds) is described.

6249-02, Session 1

Hybrid evolutionary algorithms for network-centric command and control

D. Khosla, HRL Labs., LLC; T. E. Nichols, ThalesRaytheonSystems

This paper describes a method and system for automatically allocating and scheduling defensive weapons against attacking threats to maximize desired engagement objectives. The proposed method addresses not only the weapon-target pairing problem but also the optimal launch times of the weapon systems to meet the desired objectives. We present a hybrid genetic algorithm (GA) that is a combination of a traditional genetic algorithm and a simulated annealing-type algorithm for solving these problems. The hybrid GA approach is based on a simulated annealing-type heuristic to compute the fitness of GA-selected populations. The fitness computation optimizes the temporal dimension (scheduling) under resource and temporal constraints. The proposed method provides schedules that are near optimal in short cycle times and have minimal perturbation from one cycle to the next. In addition, the solutions can be made available to the engagement operator on a just-in-time basis. By modeling engagement resource and temporal constraints of each weapon system during the optimal allocation computation process itself, each weapon system is only allocated threats that it can actually engage with maximal utilization of its resources. This will result in effective battle management even under extremely heavy attack situations that seemingly outnumber weapon resources. We compare performance of the proposed approach with other applicable algorithms.

6249-03, Session 1

Open modular embedded instrumentation architecture for test and evaluation

R. Zhou, P. C. Sanza, M. R. Durling, P. M. Szczesny, K. F. Yim, GE Global Research

Military systems in the new century are becoming increasingly complex, network centric, and information intensive. Existing ad-hoc test and evaluation (T&E) approaches are facing increasing challenges to cope with these complexities. An open, modular, standards-based embedded instrumentation (EI) architecture (OMEA) is proposed to leapfrog the capabilities of T&E. The OMEA embraces an “all digital” solution and embraces rapidly emerging commercial-off-the-shelf (COTS) hardware and software technologies. These technologies include smart sensor networks, time synchronization for sensor network, reconfigurable hardware, model based design and software defined radio.

The OMEA architecture will rationalize the myriad of heterogeneous EI and control systems. It will normalize the EI interfaces enabling easier and more cost-effective system design, development, procurement, integration and testing. With the growth of digital control platforms, it is possible to design-in EI capabilities to sense and collect critical performance data without requiring additional sensors. Any military vendor or system integrator will be able to realize this “controller is the instrument” vision by using the proposed OMEA architecture.

6249-04, Session 1

Development of an embedded instrumentation system architecture and its comparison to the test and training enabling architecture

H. E. Michel, P. J. Fortier, Univ. of Massachusetts

This paper describes an information-centric embedded instrumentation systems architecture (EISA) and in particular its technical reference model (TRM) as they relate to the network-centric test and training enabling architecture (TENA). The embedded instrumentation systems architecture is meant to describe the operational, behavioral and informational requirements for a general “embedded instrumentation test and evaluation system” encased within an operational weapons system. The weapons system application could be in a weapon round, to an entire large platform such as a warfare fighting unit, battle group or single war-craft such as a ship, plane or tank. TENA and the EISA models have much in common as will be described. The differences lie in the focus of each models intended application domain. Both are part of the military support communities for aiding the military in training, testing, evaluating, verification or validation of weapons systems.

6249-05, Session 1

Mathematical defense method of networked servers with controlled remote backups

S. Kim, SAMSUNG Electronics Co., Ltd. (South Korea)

The networked server defense model is focused on reliability and availability in security respects. The (remote) backup servers are hooked up by VPN (Virtual Private Network) and replace broken main severs immediately. The networked server can be represent as “machines” and then the system deals with main unreliable, spare, and auxiliary spare machines (network elements, subject to random breakdowns, repairs and two replacement policies: one for busy and another -for idle or vacation periods. During vacation periods, when the system performs a mandatory routine maintenance, auxiliary machines are being used for backups; the information on the system is naturally delayed. We use an analog of the N-policy to restrict the usage of auxiliary machines to some reasonable quantity. The results are demonstrated in the network architecture by using the stochastic optimization techniques.

6249-06, Session 2

Broad-area maritime surveillance unmanned aircraft system (BAMS UAS): a network centric system

R. Dishman, Naval Air Systems Command

Abstract not available

6249-07, Session 2

Networked sensors for the future force ATD

G. A. Klager, U.S. Army Night Vision & Electronic Sensors Directorate

Abstract not available

6249-09, Session 2

Summary of the first network-centric sensing community workshop, ‘Netted sensors: A government, industry and academia dialogue’

L. D. Tromp, G. M. Jacyna, The MITRE Corp.

Abstract not available

6249-10, Session 2

Tactical optical systems for network-centric environment

P. G. Tomlinson, Solers, Inc.; J. C. Ricklin, Defense Advanced Research Projects Agency

Abstract not available

6249-11, Session 2

Distributed Kalman filter tracking algorithms for ad hoc acoustic sensor network

T. Pham, Army Research Lab.

In this paper, we present distributed algorithms for tracking a moving source via an ad-hoc network of acoustic sensors. Tracking is performed by employing a Kalman filter at all detecting nodes in the network. The Kalman filter employed at any given node exploits the availability of source-location snapshot and prediction estimates, both of which are computed via distributed locally constructed algorithms over the ad-hoc network. As our simulation-based analysis reveals, the source-tracking performance of the proposed algorithms is a function of the motion dynamics of the source, the snapshot source-localization algorithm employed, the network topology, and the number of iterations employed in the distributed approximation algorithm.

6249-12, Session 2

Powered low-cost autonomous attack system: a network-centric munition concept demonstration

J. C. Savage, J. K. O’Neal, R. A. Brown, Air Force Research Lab.

The Powered Low Cost Autonomous Attack System (PLOCAAS) is an Air Force Research Laboratory Munitions Directorate Advanced Technology Demonstration program. The PLOCAAS objective is to demonstrate a suite of technologies in an affordable miniature munition to autonomously search, detect, identify, attack and destroy ground mobile targets of military interest.

PLOCAAS incorporates a solid state LADAR seeker and Autonomous Target Acquisition (ATA) algorithms, miniature turbojet engine, multi-mode warhead, and an integrated INS/GPS into a 36" high lift-to-drag airframe. Together, these technologies provide standoff beyond terminal defenses, wide area search capability, and high probability of target report with low false target attack rate with high loadouts. Four LADAR seeker captive flight tests provided the sequestered data for robust Air Force ATA algorithm performance assessment. PLOCAAS has had three successful free-flight tests in which the LADAR seeker and Autonomous Target Acquisition (ATA) algorithms have detected, acquired, identified, and tracked ground mobile targets.

In addition to summarizing all program accomplishments, this paper will present results and lessons learned from the latest phase of PLOCAAS development. This phase’s objective was to demonstrate the military utility of a two-way data-link. The data-link allowed Operator-In-The-Loop monitoring and control of miniature cooperative, wide-area-search munitions and enables them to serve as non-traditional Intelligence, Surveillance, and Reconnaissance (ISR) assets in a network-centric environment.

6249-13, Session 2

Aircraft voice intercommunications system design for Project Oculus

J. Wilhelm, West Virginia Univ.

Project Oculus, an ongoing research platform for deploying airborne sen-

sors on a C-130 aircraft, is currently in its pre-flight testing phase. The sensor platform is divided into two systems that rest on standard 463L pallets-a sensor pallet and an operator station. The sensor pallet consists of a deployment arm and a pod containing various sensors such as an infrared camera, radar, high resolution visible light cameras and many others. The operator station houses power control equipment, data acquisition, and two operators controlling the sensors.

Oculus is designed to fly on a C-130 aircraft, which has very high internal audible noise. Although Oculus' operator station contains noise-deadening material, a headset intercommunication system must be designed with different headset standards, communicate with the C-130 intercom, and be expandable to accommodate various audio sources such as radios and satellites.

Throughout the years, intercom systems and headsets have evolved from an original standard consisting of a impedance rating of a speaker and a microphone. Early intercom systems were highly limited in functionality and quality due to simple electronics and common grounding. Advances in electronics allowed for the evolution of headset standards and intercom equipment, which permitted a multitude of new configurations and improved sound quality. Because of these advances, multiple headset standards and intercom interfaces have become popular among military and civilian aviation.

Due to the different standards of headsets, impedance matching plays a major role in the design of an intercom system. Oculus is a multi-mission platform, and must be designed to support major standards of both civilian and military headsets. This paper will outline intercom units and parts considered for use in Oculus, and a design for an expandable intercom system for Oculus.

6249-14, Session 3

Near space: a new frontier

J. R. Guerci, Defense Advanced Research Projects Agency

Abstract not available

6249-15, Session 3

A network-centric approach to space situational awareness

D. A. Whelan, A. Galasso, A. Adler, The Boeing Co.

Abstract not available

6249-17, Session 4

Demonstrating tactical information services from coordinated UAV operations

J. S. Bay, Air Force Research Lab.

Abstract not available

6249-18, Session 4

Cooperative operations in urban terrain

D. C. Gross, General Dynamics Advanced Information Systems; J. Casey, Air Force Research Lab.; S. J. Rasmussen, General Dynamics Advanced Information Systems

An investigation is ongoing to evaluate the behavior of Small Unmanned Aerial Vehicles (SUAVs) and Micro Aerial Vehicles (MAVs) flying through an urban setting. This research is being conducted through the Air Force Research Laboratory (AFRL) Cooperative Operations in UrbaN TERrain (COUNTER) 6.2 research and flight demonstration program. This is a theoretical and experimental program to develop the technology needed to integrate a single SUAV, 4 MAVs, and a human operator to perform persistent intelligence, reconnaissance and surveillance for obscured targets in an urban environment. The research involves development of six-degree-of-freedom models for integration into simulations, modeling and integration of wind data for complex urban flows, cooperative control task assignment and path planning algorithms, video tracking and obstacle avoidance algorithms, and an Operator Vehicle Interface (OVI) system. The COUNTER concept and the contributing technologies will be proven via a series of flight tests and system demonstrations.

The first on five planned COUNTER flight demonstrations occurred in July of 2005. This demonstration focused on the simultaneous flight operations of both the SUAV and the MAV while displaying their respective telemetry data on a common ground station (OVI). Current efforts are focused on developing the architecture for the Cooperative Control Algorithm. In FY 2006, the COUNTER program will demonstrate the ability to pass vehicle waypoints from the OVI station to the SUAV and MAV vehicles. In FY 2007, the COUNTER program will focus on integrating solutions to the optical target tracking (SUAV) and obstacle avoidance (MAV) issues into the capabilities of the OVI station and Cooperative Control Algorithm.

6249-19, Session 4

An information-based approach to decentralized multiplatform sensor management

C. M. Kreucher, K. D. Kastella, J. W. Wegrzyn, B. Rickenbach, General Dynamics Advanced Information Systems

This paper presents a decentralized low communication approach to multiplatform sensor management. The method is based on a combination of information theory and physicomimetics, which inherits the benefits of information theoretic scheduling while maintaining tractability. The method uses only limited message passing, only neighboring nodes communicate, and each node makes its own sensor management decisions. We show by simulation that the method allows a network consisting of a large number of nodes to automatically self organize to perform a global task.

We illustrate our method by simulation on the following model problem. There are a number of unmanned aerial vehicles (UAVs) hovering above a ground surveillance region. There are an unknown number of moving ground targets in the region. Each UAV is capable of making measurements of the patch of ground directly below, and these measurements provide evidence as to the presence or absence of targets in that subregion. The goal of the network is to learn the number of targets and their individual states (positions and velocities) through repeated interrogation of the ground. As the individual nodes can only see a small portion of the ground, they need to move in response to the measurements so that the entire region is surveyed over time. Thus, in this setting each node uses a sensor management algorithm to choose how to move.

6249-20, Session 4

A tracking approach to localization and synchronization in mobile ad hoc sensor networks

P. Bidigare, C. M. Kreucher, R. Conti, General Dynamics Advanced Information Systems

Self localization is a term used to describe the ability of a node to automatically determine where it is given little or no prior information. Self localization is an enabling technology for many future sensing capabilities; specifically those that rely on a large number of sensors that are to self organize to form a coherent system. Most of the prior work in this area focuses on centralized computation with stationary nodes and perfectly synchronized clocks. We consider a setting that is more general in three ways. First, nodes in the network are moving. This motion implies that the pair wise distances between nodes is not fixed and therefore an iterative tracking procedure must be used to estimate the time varying node positions. Second, we do not assume synchronization between clocks on different nodes. In fact, we allow the clocks to have both an

unknown offset and to be running at different rates (i.e., a drift). Third, our method is decentralized, so that there is no need for a single entity with access to all measurements. In this setup, each node in the network is responsible for estimating its state.

The method is based on repeated pair wise communication between nodes to hat produce observables informative to the nodes in the network. We focus on two types of observables in this paper. First, we use the time between when a message was sent from one node and when it was received by another node. In the case of synchronized clocks, this observable provides information about the distance between the nodes. In the more general case with non-synchronized clocks, this observable is coupled to the clock offsets and drifts as well as the distance between nodes. Second, we use the Doppler stretch observed by the receiving node. In the case of synchronized clocks, this observable provides information about the line of sight velocity between the nodes. In the case of non-synchronized clocks, this observable is coupled to the clock drift as well as the line of sight velocity. We develop a sophisticated mathematical representation, based on Lie Groups, that allows all of these effects to be accounted for simultaneously.

We approach the problem from a Bayesian point of view, where measurements are accumulated over time and used to form a probability density on the (time varying) state conditioned on the measurements. What results is a recursive filtering (or "tracking") algorithm that optimally synthesizes the measurements together. We show by simulation that our method provides an efficient decentralized method for determining the location of a collection of moving nodes.

6249-21, Session 4

Considering dendritic networks: a perspective approach to network-enabled information

D. W. Prior, General Dynamics United Kingdom Ltd. (United Kingdom)

Network-centricity brings compounding effects to the volumes of data generated across the battlespace: effects that directly impact the levels of processing and management necessary to ensure 'rightput'. In the context of transformation, the risk arises that technology may create a data flood for which extant doctrine, organisation, and - above all - personnel may be unprepared. Alongside constraints in bandwidth, processor cycles, and time, human attention and psychology is expected to become a bottleneck in the achievement of necessary 'rightput'.

This paper presents a consideration of 'dendritic networks': a data and information perspective that utilises a biologically inspired cognitive architecture to address these issues. Derived from research into distributed sensors, dynamic networks, and new approaches to machine intelligence, such architectures take account of the sensing and processing mechanisms observed in biology and neuroscience. This paper suggests that a scalable dendritic metaphor would reduce increasing data volumes to contextual information that directly supports the warfighter.

Beyond an introduction to the 'dendritic networks' model for data and information management, this paper will present indications of areas where similar models may be implemented. Opportunities for the use of dendritic techniques where multiple co-operating elements must take account of disparate multi-variant information to successfully achieve intent will be highlighted and, where possible, illustrated through simulation.

'Dendritic networks' are a new approach to the problems of network-enabled information. Aspects of ongoing research, development, and application environments will be included with the intention of stimulating further discussion and forging a community of common interests.

6249-22, Session 4

Reliable service discovery for network-centric systems

R. M. Bradford, G. W. Daugherty, K. Ghoshdastidar, Rockwell Collins, Inc.

This paper describes a service-oriented architecture for network-centric operations that can enable Reliable Service Discovery (RSD). The goal is to support the Network Centric Warfare (NCW) concept of effective linking among entities in the battlespace. We believe that a scalable middleware architecture that enables RSD is a key component of a robust, high-performance infostructure that supports seamless interactions among battlespace entities. We define metrics for characterizing service discovery reliability. We then analyze several complementary mechanisms for improving reliability and for exploiting the collaborative effects of information sharing. These mechanisms include distributed service registries, the replication of individual registry entries rather than entire registries, periodic revalidation of registry data and the efficient propagation of registry updates, and adaptive reconfiguration of the registry topology in response to changes in network membership and connectivity and in missions and mission priorities. In general, we assume that mobile ad hoc networks operating in tactical environments will include significant numbers of devices with limited battery power, broadcast range, bandwidth, processing capability, and data storage. Wherever possible, we seek to offload the burden of service discovery onto the registry nodes, which we assume, all other things being equal, will have fewer resource limitations. This is consistent with the NCW principle of relocating complexity from the platform to the network. We outline directions for further research, including an approach that uses adaptive intelligent registry proxies to implement strategies for peer-to-peer caching and the sharing of registry information when appropriate from both the system and the individual client perspectives.

6249-23, Session 4

Autonomous collaborative behaviors for multi-UAV missions

Y. Chen, M. A. Peot, J. Lee, V. Sundareswaran, T. W. Altshuler, Rockwell Scientific Co., LLC

Self-organizing, collaborative multi-UAV teams that rely on little or no human guidance have the potential to dramatically increase ISR/RSTA functionality. In this concept, users would be able to set up high-level behaviors based on mission needs, and have the multi-UAV teams execute these behaviors autonomously. We believe that the most critical element of this concept is a robust, extensible, modular architecture. As part of an Army program on multi-UAV collaboration, we have been developing an extensible architecture and behavior planning / collaborative approach, named Autonomous Collaborative Mission Systems (ACMS). The architecture is modular and the modules may be run in different locations/platforms to accommodate the constraints of available hardware, processing resources and mission needs. The modules and uniform interfaces provide a consistent and platform-independent baseline mission collaboration mechanism and signaling protocol across different platforms. Further, the modular design allows flexible and convenient extension to new autonomous collaborative behaviors to the ACMS. In this report, we describe a set of autonomous collaborative behaviors, including collaborative area surveillance, collaborative point observations, and assured communications, implemented in the ACMS architecture and the simulation results for these behaviors.

6249-24, Session 4

Experimentation to support network-centric capabilities

P. S. Gaertner, T. Moon, Defence Science and Technology Organisation (Australia)

Defence is currently faced with a wide range of new challenges including the war on terror, force transformation, expeditionary operations and joint warfighting, reducing the cost of operations, and declining skilled human resources. In addition to these, the rate of technology evolution is outstripping the capacity for Defence Forces to absorb new opportunities or even conceptualise the emergent concepts of operation. Maintaining a capability edge in such a dynamic, fast moving technology environment

is yet another challenge for the Australian Defence Force (ADF). Furthermore, the military environment is riddled with advances in military related technologies, new operational concepts and ever increasing and evolving threat conditions. Within the ADF military experimentation has become an extremely important mechanism in the exploration and subsequently exploitation of these changing conditions, and network-centricity is being used to determine the most appropriate mix of emerging and legacy systems and assimilate into a coherent framework.

One of the major challenges for the ADF in using an experimentation approach for network-centric capabilities is to clearly identify what it is seeking to achieve. To that end this paper describes the network-centric warfare and experimentation initiatives currently being undertaken within the Defence Science and Technology Organisation. It outlines how these initiatives are collaborating to integrate its numerous warfighting activities into a coherent program of work with clear goals and priorities set at the senior levels of capability development to inform future interactions of the ADF Network-Centric Warfare roadmap on the above issues.

6249-25, Session 4

Applicability of operations research to the practice of experimentation

P. S. Gaertner, F. D. Bowden, D. K. Bowley, Defence Science and Technology Organisation (Australia)

Defence has embraced an approach to capability and concept development that incorporates a model of experimentation. Although the approach taken is conceptually consistent with the empirical notion of an experiment, its domain of implementation differs greatly. As a consequence a greater need for evolution in tools and techniques is required. The domain of application of experimentation is predominately large scale systems with high proportion of humans-in-the-loop, such as force structures, the effectiveness of extensive networks, or different command structures. The United States, through its Command and Control Research Program has explicitly addressed the need for a Code of Best Practice in applying experimentation to capability enhancement. The aim of this paper is three-fold: (1) to argue that any such code of practice must utilise the foundations of operations research; (2) to review the current practice of force-level military experimentation in Australia and describes the applicability of operations research within that practice to encompass a program of activities; and (3) to describes how experimentation is and has been utilised within the Australian Defence Force to investigate, evaluation and inform senior decision-makers on warfighting concepts, capability and technology development and organisational structures.

6249-26, Session 4

A field investigation of radio network usage at the dismounted infantry section level

J. Frim, Defence Research and Development Canada (Canada); D. W. Tack, Humansystems Inc. (Canada); L. L. M. Bossi, Defence Research and Development Canada (Canada)

The Soldier Information Requirements Technology Demonstration (SIREQ TD) project is an experimentation program to identify technologies that significantly enhance the performance of our future soldiers. One of the study series involved a 2 x 2 factorial comparison of the benefits of digital maps over paper maps, and the use of radios vs no radios. Thirty-two Canadian regular force infantry soldiers performed force-on-force tactical assault missions in wooded terrain, with each soldier participating in all four test conditions. The radios were configured to operate in 4 subnets: 1 channel for each of the 2 Assault Groups (4 soldiers on a channel); a Section Commander/2IC channel; and an all-users channel. Note that in the no-radio conditions soldiers still operated the press-to-talk switch to allow recording of communications, but the speaker volume was set to zero. All communications were date/time stamped, identified as to the user and channel, and the audio was digitally recorded for later analysis as to the nature and content of the message. The study showed that although the type and function of communication did not change dramatically across the four test conditions, there was an increased amount of overall communication when soldiers carried radios compared to when they did not. Other quantitative results pertaining to communications, situational awareness, perceived workload, and team effectiveness will be presented, along with subjective measures collected by questionnaires and focus group discussions.

6249-27, Session 4

Investigation of alternative organizational structures

D. W. Tack, Humansystems Inc. (Canada); L. L. M. Bossi, J. Frim, Defence Research and Development Canada (Canada)

A number of studies were conducted under the Soldier Information REQuirements Technology Demonstration (SIREQ-TD) project to investigate the use of digitally-enabled enhancements in select dismounted infantry mission phases for planning, navigation, information exchange, target engagement, communication, and situation awareness. Results suggest that a digitally-enabled platoon should have higher situation awarness, a better common operating picture of the battlefield, a greater span of control with wider tactical separation of sub-units, increased operational tempo, and a greater ability to employ independent unit manoeuvre and actions than a conventional non-digitally enabled platoon. These digitally-enabled capabilities suggest that the principles of mission command and swarming formations could also be employed to effect with distributed operations in a Network Centric Warfare environment. If that were the case, is the current organizational structure of the dismounted infantry platoon the most effective option for exploiting these benefits?

To evaluate the effect of digitization on platoon effectiveness and investigate the suitability of different platoon structures, a twelve-day field trial was undertaken with a Company of light infantry at Fort Benning, Georgia. Test missions were conducted in both day and night conditions, in wooded and urban terrain environments, in each of three organizational structures, with and without digitization. The three different organizational structures included our current in-service 8-man Section, a 13-man USMC squad, and a distributed model comprising six four-man teams. Results of this study confirmed that the effectiveness of a dismounted platoon is signficantly enhanced by the use of select digital enhancements in the areas of navigation, situation awareness, communications, and command. During night operations, digitally-enabled capabilities were the difference between mission success and failure. None of the organizational structures tested proved to be universally better than the others at optimizing the benefits of digitally-enhanced capabilities, although each had their strengths and weaknesses. However, considerable insights were gained in the organizational structure issues of distributed small unit command and control, swarming formation tactics, and the tactics, techniques, and procedures necessary to employ small units effectively in a NCW environment.

6249-28, Session 4

A mathematical approach for mission planning and rehearsal

E. Gelenbe, Y. Wang, Imperial College London (United Kingdom)

The world that we live in is filled with large scale agent systems, from diverse fields such as biology, ecology or finance. Inspired by the desire to better understand and make the best out of these systems, we propose an approach which builds stochastic mathematical models, in particular G-networks models. This work complements our previous results on the discrete event simulation of adversarial tactical scenarios. We aim to provide insights into systems in terms of their performance and behavior, to identify the parameters which strongly influence them, and to evaluate how well individual goals can be achieved. With our approach, one can compare the effects of alternatives and chose the best one available. We model routine activities as well as situations such as: changing plans

(e.g. destination or target), splitting forces to carry out alternative plans, or even changing on adversary group. Behaviors such as competition and collaboration are included. We demonstrate our approach with some urban military planning scenarios and analyze the results. This work can be used to model the system at different abstraction levels, in terms of the number of agents and the size of the geographical location. In doing so, we greatly reduce computational complexity and save time and resources. We conclude the paper with potential extensions of the model, for example the arrival of reinforcements, the impact of released chemicals and so on.

6249-29, Session 6

Autonomous mobile mesh networks and applications for defense network-centric operations

A. R. Sastry, PacketHop, Inc.

This paper presents an overview of mobile mesh networking technology and multimedia applications that support mission-critical operations for network-centric tactical defense operations. Such broadband, autonomous, rapidly deployable, and secure communications and distributed applications provide survivable and reliable means of providing timely information to military forces to gain information superiority and support efficient mission execution. In this paper, first, the communications requirements for such highly dynamic battlefield environments are outlined. The need for and value of autonomous broadband mobile mesh networks and a variety of multimedia applications such as multicast video, location and tracking, white-boarding, and distributed interactive messaging are then described. This is followed by an overview of technical challenges that need to be addressed for providing these services over autonomous mobile mesh networks. Finally, an example of an actual implementation of such a network and services is briefly described to highlight the potential of this solution for defense services.

6249-30, Session 6

Net-centric optical communications for the global information grid

A. Dwivedi, Johns Hopkins Univ.

In the DoD vision of network-centric warfare (NCW), the warfighter becomes an edge node in a seamless internetwork known as the Global Information Grid (GIG). This net-centric architecture enables communications anywhere and anytime as long as the user has access to the GIG. The information services data streams supported by the GIG traverse over a heterogeneous network of networks including high-capacity terrestrial fiber-optic network, namely GIG-BE, transformational satellite communications such as TSAT, and wireless access communication links provided by JTRS.

Traditional RF-based wireless communication systems have significant bandwidth limitations, especially as compared to the terrestrial fiber-optic networks (e.g. GIG-BE). The future adoption of many bandwidth intensive military sensors, sensor networking applications, and sensor fusion applications is likely to increase the traffic demands for the edge networks. In addition, a multi-layer net-centric approach will add layer-specific protocol overhead requiring additional physical layer bandwidth. Since the GIG internetwork is simultaneously shared among many users with unpredictable traffic demands, excess network capacity is needed to accommodate aggregate traffic bursts. Collectively, this presents a significant technical challenge to the NCW vision of ubiquitous data access at the edge since the traditional systems may become a bottleneck for many future bandwidth-intensive warfighting applications.

Optical communications is being actively explored as a potential solution not only to alleviate the bandwidth bottlenecks but also to provide covert, jam resistant communications without spectrum restrictions. This paper presents an analysis of inherent benefits of optical wireless communications technologies in enabling net-centric applications, and reveals specific challenges that need to be overcome before optical wireless technologies can be implemented in the Global information Grid to realize the NCW vision.

6249-31, Session 6

A survey and comparison of distributed systems for group communications suitable for network-centric warfare

J. L. Hester, National Ctr. for Supercomputing Applications and Univ. of Illinois at Urbana-Champaign; W. J. Yurcik, National Ctr. for Supercomputing Applications; R. H. Campbell, Univ. of Illinois at Urbana-Champaign

In this work we survey distributed systems that can provide group communications; both existing commercial systems and proposed research systems. Distributed systems are compared across multiple architectural characteristics such as fault-tolerance, scalability, security, delivery guarantees, and management as well as contrasted against systems utilizing peer-to-peer systems, application-level multicast, and IP layer multicast. Comparing distributed systems which provide group communications is a step toward developing systems appropriate for military network-centric group communications where more research is needed. A secondary result is an attempt to merge group communications terminology between distributed systems, peer-to-peer, application-layer multicast and IP layer multicast.

This work builds on previous work from this conference [1,2]

1 C. Abad, W. Yurcik, R. Campbell, “A Survey and Comparison of End-System Overlay Multicast Solutions Suitable for Network Centric Warfare,” In Proc. of SPIE, 2004.

2 Z. Anwar, W. Yurcik, R. Campbell, “A Survey and Comparison of Peer-to-Peer Group Communication Systems Suitable for Network-Centric Warfare,” In Proc. of SPIE, 2005.

6249-32, Session 6

Framework for visualization of battlefield network behavior

Y. A. Perzov, W. J. Yurcik, Univ. of Illinois at Urbana-Champaign

An extensible battlefield network visualization framework was developed. The application monitors node mobility and renders broadcast and unicast network traffic behavior. Broadcast and unicast traffic are depicted as expanding rings and directed links. The package was specialized to support fault injections, specifically to show the effected area of an air strike and disabling of nodes. The framework provides capability for two types of graphs, histogram and x/y plots. The framework takes standard NS trace files as an input. Output can be saved in AVI format. The framework can be adapted to take real time input from any data source, serving as a basis for a real time battle field awerness system.

6249-33, Session 7

Node link stability in wireless mobile networks

I. Hokelek, M. U. Uyar, City College/CUNY; M. A. Fecko, Telcordia Technologies, Inc.

We introduce a novel analytic model for ad hoc networks based on Markov chains whose states represent node degree and the number of link failures. The model divides a geographic area into logical hexagonal cells, where random walk with probabilistic state-transition matrix determines link creation/failure. We can thus compute two important metrics characterizing the dynamics of a node’s random movement: the expected times for the number of link changes to drop below and for the node degree to exceed a threshold. We obtained the two-dimensional Markov chain that allows us to apply these two metrics as the selection rules for the virtual backbone formation algorithm. Hence, our model is used to analyze the

performance of service discovery architectures based on virtual backbone in mobile ad-hoc networks. We also plan to extend the created modeling framework to derive a number of additional metrics that characterize network connectivity, capacity, and survivability.

Because the model is capable of computing the dynamics and the expected value of the number of a node's neighbors, it can also be used to estimate the level of interference as well as achievable and sustainable routing path diversity, degree of network connectivity, and the stability of routing tables. We expect to apply our modeling framework to analytic assessment of the stability of routing domains. The rate and expected values at which the nodes move in and out of domains characterize the rate of degradation of optimally built routing domains, and hence the resulting routing scalability and overhead.

6249-34, Session 7

The impact of COTS technologies on the military and how to ensure security across the GIG

D. H. Minton, World Wide Consortium for the Grid

In order to ensure interoperability, as well as a high level of security, among the various agencies, bureaus, first responders, and NGOs who may respond in an emergency, the government must take ownership of critical security features.

To a certain extent, this is already done. Many encryption techniques currently in use are based on Secure Hash Algorithm (SHA-1), which was designed by the National Security Agency (NSA) and the standard is published and maintained by the National Institute of Standards and Technology (NIST). NSA owns type 1 encryption, but other elements of security, however, have neither clear ownership nor clear definition. The government needs to define these core capabilities, like they have confidentiality. These core capabilities include authentication, authorization, nonrepudiation and identity.

Until this is done, various vendors will be compelled to continue competing with each other for the "best" or "most marketable" implementation-but because these services are core to the security of the national network infrastructure, the government cannot afford to let a proprietary solution become the standard. David Minton, chief engineer for W2COG, will discuss his work with the government, academia, and industry to establish and define these basic elements, then publish working reference implementations, from which the standards and commercial products and implementations may be developed.

6249-35, Session 7

Simulation of mobile ad hoc networks with free-space optical capabilities

P. Yan, J. J. Sluss, Jr., H. H. Refai, Univ. of Oklahoma; P. G. LoPresti, Univ. of Tulsa

Mobile ad hoc networks (MANETs) offer a cost-effective solution for communications in areas where infrastructure is unavailable, e.g. the so-called "last mile" and disaster recovery situations. Traditional MANETs operate in the radio frequency (RF) spectrum, where the available bandwidth is facing the challenge of rapidly increasing demands. Free-space optics (FSO) provides an attractive enhancement to RF wireless MANETs because of its high bandwidth and interference-free operation. Such an enhanced MANET especially suits the needs of battlefield scenarios, where increasingly broad bandwidths in mobile networks are desired. In this paper, we present our ongoing research efforts in enhancing the performance of MANETs by introducing an FSO module to the communication nodes. Computer models of such a hybrid MANET were created in the environment of OPNET Modeler, a network simulation software package. Various issues related to the performance of such a network were simulated and analyzed. The analysis will be of great assistance in the design and implementation of such next-generation MANETs.

6249-36, Session 7

Traffic forecaster for MPLS multimedia data streams

B. E. Ambrose, F. S. Lin, Broadata Communications, Inc.

Contemporary high performance data networks carry a wide range of multimedia services (voice, video, audio, text, sensor data, etc.) that require an outstanding Quality of Service (QoS) to provide performance guarantees in priority delivery, latency, bandwidth utilization, load balancing, etc. With the advent of recent Multi-Protocol Label Switching (MPLS) network standards, the QoS has made significant progress in performance to provide these performance guarantees. Right now, attention has turned to the task of managing these QoS networks more efficiently through the handling of network traffic. We are investigating a novel Network Traffic Forecasting Assisted QoS Planner technology that will provide constantly updated forecasts of data traffic and server loads to any application that needs this information. Using source models of voice, video and data traffic based on empirical studies of TCP/IP data traffic carried out by Paxson and Floyd in the 1990's, our studies have shown that the system may provide up to 43% bandwidth savings for MPLS data streams, by predicting future traffic flows and reserving network resources to accommodate the predicted traffic. The system additionally provides a means to submit bandwidth reservation requests for those applications that need assured service guarantees for data delivery. The technology essentially increases the efficiency and effectiveness of multimedia information and communication network infrastructure that supports multiple or adaptive QoS levels for multimedia data networking and information system applications.

6249-37, Session 7

Universal Autosophy data formats for network-centric systems

K. E. Holtz, Autosophy

Converting conventional platform-centric multimedia communications to the new network-centric packet switching systems, like the Internet, requires a paradigm change in how we define "communication".

Multimedia data is now communicated in meaningless bit streams according to the Shannon information theory. This is not the way human or biological creatures communicate. An alternative communication paradigm is now evolving based on the Autosophy information theory. Communication involves "meaning" or data contend, expressed in "addresses", which is universally compatible and hardware independent. The theory evolved from research into self-assembling natural structures, such as chemical crystals or living trees. The same natural laws and principles can also produce self-assembling data structures that grow like data crystals or data trees in electronic memories, without computing or programming. The resulting learning algorithms are used to grow hyperspace libraries for communication and archiving. The advantages would include: high lossless data compression; unbreakable "codebook" encryption; high resistance to transmission errors; universally compatible data formats; and virtual immunity to the Internet's Quality of Service (QoS) problems. A new 64bit content-based universal data format was recently developed for Internet television to allow real time multimedia data communication via the Internet. The new data formats are ideally suited to the Internet's packet switching environment. All multimedia data can be converted to the universal 64bit format by simple software patches or integrated chipsets. Data can be forwarded through any media: radio, satellites, Internet, or cable, without needing to be reformatted. The data formats may be phased in slowly without disruption to existing communications.

Conference 6250: Mobile Multimedia/ Image Processing for Military and Security Applications

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6250-01, Session 1

Reduced memory JPEG decompression for mobile devices

E. Z. Ioup, H. Mesick, J. T. Sample, F. P. McCreedy, Naval Research Lab.

Imagery makes up a large percentage of homeland security data in use today. One feature of this imagery is that it tends to be large, often hundreds or thousands of megabytes. As a result, JPEG compression is often used to make this imagery manageable by reducing the file size without greatly reducing the quality of the image. However, the benefits of compression are absent when the image is viewed. Viewing a large JPEG image requires decompressing and holding the uncompressed version in memory. Holding the entirety of a large image in memory is problematic on mobile computers with limited system resources. However, the entire image is rarely needed at full resolution. Usually only a small area of interest may be viewed given the limits of screen size. This paper describes a method of retrieving a small area of interest from a large JPEG without decompressing the entire image. JPEG compressed images are streams which cannot be randomly accessed. Viewing a particular area requires that all preceding areas be partially decompressed. This process is more efficient than fully decompressing the whole JPEG, but depending on the area requested the entire image may need to be partially decompressed. To circumvent this problem an index file records markers for the sections of the JPEG allowing random access to any portion of the file. This method of decompressing a JPEG requires a limited amount of memory and is faster than traditional JPEG decompression making perfect for smaller mobile devices.

6250-02, Session 1

An efficient real-time video compression algorithm with high-feature preserving capability

N. Al-Jawad, J. H. Ehlers, S. A. Jassim, Univ. of Buckingham (United Kingdom)

In this paper we are concerned with high quality video compression for constrained mobile devices. Recently, we have introduced such a feature-preserved image compression technique that exploits the statistical properties of wavelet subbands of the image. When applied to compress a video frame-by-frame, it resulted in high frame rate (over 20 fps), and outperformed JPEG and JPEG2000 in terms of modified PSNR measures. The relatively high compression, speed and image quality make such an algorithm suitable for implementation on low cost mobile devices. In this paper we shall report on a modified implementation of this feature-preserving compression, specifically designed for efficient implementation on mobile devices such as PDA's. The main modification is based on the observation that in many cases the statistical parameters of wavelet subbands of adjacent video frames do not differ significantly. This would allow significant bandwidth and processing-time saving without loss of quality. And that might be suitable for biometrics or other similar security applications. This will allow the re-using of codebooks for adjacent frames. Codebook will be produced for only a limited number of frames and these frames will nominated in a certain interval. This will have a very limited effect on the quality aspect if any, and will achieve more compression by discarding the codebooks from the non-key frames images. This performance of this scheme will be tested against other video compression methods. Such a scheme is expected to be of use in security applications such as transmission of biometric data.

6250-03, Session 1

Compression-designs for efficient intelligent systems

E. H. Feria, College of Staten Island/CUNY

In this paper a novel methodology, Compression-Designs, is advanced for the design of efficient intelligent systems. The approach borrows ideas from signal (or source) coding to design "complexity compressed" intelligence processors (IPs) that operate on highly compressed intelligence. The technique has been successfully applied to a real-world knowledge-aided (KA) airborne moving target indicator (AMTI) radar system subjected to severely taxing disturbances. The considered intelligence was clutter, in the form of synthetic aperture radar (SAR) imagery, and the IP was a complexity uncompressed clutter covariance processor (UCCP). A key result obtained was the appearance of a paradigm shift in the way that system designers should view the design of efficient IPs since the complexity compressed clutter covariance processor (CCCP) achieves significantly better radar performance than the UCCP when operating on highly compressed information. It is possible that Compression-Designs may be applied to the design of efficient IPs for cell phone data bases.

6250-04, Session 1

A lossless predictive-transform signal coding algorithm for compression-designs-based intelligent systems

E. H. Feria, D. Licul, College of Staten Island/CUNY

In this paper a "lossless" predictive-transform (PT) signal (or source) coding algorithm is offered for compression-designs based intelligent systems (CDBIS) that compress/decompress both the intelligence or signal and intelligence processor or system to yield great improvements in both storage and computational speeds (see Proceedings of the DARPA KASSPER Workshops, 2002-2005 and the feria.csi.cuny.edu web site that will be posting excerpts from a DARPA KASSPER Grant Final Report). The CDBIS case that is used to illustrate our algorithm is a knowledge-aided (KA) airborne moving target indicator (AMTI) radar where the prior knowledge used is synthetic aperture radar (SAR) imagery which results in significant clutter rejection. The prior knowledge, i.e., the intelligence or signal, of the intelligent system is "signal (or source) coded", i.e., compressed/decompressed, using a compression-design that is unaware of the radar antenna pattern and range bin geometry (RAPRBG) and therefore is said to be "radar-blind". In this paper we advance a novel lossless PT signal coding algorithm to be used as part of a radar-blind compression-design for the signal coding of SAR images. This scheme consists of the lossless encoding of the linearly quantized n-dimensional coefficient errors emanating from a "lossy" predictive-transform coder using a simple, fast and novel recursive bit-plane approach. This integrated lossy/lossless PT coder when used as a radar-blind compression-design for SAR images, results in significant improvements over other widely used schemes. For example when applied to a SAR image of the Mojave Airport in California it results in signal to noise ratio (SNR) improvements of more than 15 dBs and 5 dBs over JPEG and JPEG2000, respectively, when the SAR image was compressed from 4 megabytes to 4 kilobytes.

6250-05, Session 1

Multiple masks-based pixel comparison steganalysis method for mobile imaging

S. S. Agaian, The Univ. of Texas at San Antonio; G. L. Peterson, B. M. Rodriguez II, Air Force Institute of Technology

Steganalysis has many challenges; one of the more difficult ones includes the accurate and efficient detection of hidden content within digital images. This paper presents a new multi pixel comparison method used for blind detection of steganographic content within digital images. The key thought of the presented method is to increase the sensitivity of features when alterations are made within the bit planes of a digital image. Differences between the new method and existing pixel comparison methods are: multiple masks of different sizes are used to increase the sensitivity along with weighted features used to improve the classification of the feature sets. The weights are used with various pixel comparisons to ensure proper sensitivity when detecting bit plane modification within the image. The article also investigates the reliability of detection and estimation length of hidden data within wireless digital images with potential for military applications emphasizing on defense and security. Testing of 100 lossless images has shown detection accuracy in determining the estimation length for our proposed method up to 25% embedded information. This is an improvement in detection accuracy when compared to existing well known techniques which diminish in accuracy after 5% embedded information.

6250-06, Session 2

SecurePhone: a mobile phone with biometric authentication and e-signature support for dealing secure transactions on the fly

R. Ricci, Informa Contract Research Organization (Italy); G. Chollet, Ctr. National de la Recherche Scientifique (France) and Ecole Nationale Supérieure des Télécommunications (France); M. V. Crispino, Nergal (Italy); S. Garcia-Salicetti, Institut National des Télécommunications (France); S. A. Jassim, Univ. of Buckingham (United Kingdom); J. Koreman, Univ. des Saarlandes (Germany); M. Olivar-Dimas, Telefonica Moviles Espana S.A.U. (Spain); P. Soria-Rodriguez, Atos Origin S.A. (Spain)

The experience of the SecurePhone project is presented, with an account of the first results obtained. SecurePhone's primary aim is to realise a mobile phone prototype - the "SecurePhone" - in which biometrical authentication enables users to deal secure, dependable transactions over a mobile network. The SecurePhone is based on a commercial PDA phone supplemented with specific software modules and a customised SIM card. It integrates in a single environment a number of advanced features: access to cryptographic keys through strong multimodal biometric authentication; appending and verification of digital signatures; real-time exchange and interactive modification of (e-signed) documents and voice recordings. SecurePhone's "biometric recogniser" is based on original research. A fused combination of three different biometric methods - speaker, face and handwritten signature verification - is exploited, with no need for dedicated hardware components. The adoption of non-intrusive, psychologically neutral biometric techniques is expected to mitigate rejection problems that often inhibit the social use of biometrics, and speed up the spread of e-signature technology. Successful biometric authentication grants access to SecurePhone's built-in e-signature services through a friendly user interface. Special emphasis is accorded to the definition of a trustworthy security chain model covering all aspects of system operation.

The SecurePhone is expected to boost m-commerce and open new scenarios for m-business and m-work, by changing the way people interact and improving trust and confidence in information technologies, often considered intimidating and difficult to use. Exploitation plans will also explore other application domains (physical and logical access control, securised mobile communications).

6250-07, Session 2

Performance evaluation of wavelet-based face verification on a PDA-recorded database

J. H. Ehlers, H. Sellahewa, S. A. Jassim, F. Stumpf, Univ. of Buckingham (United Kingdom)

Mobile communication devices have become an essential part of our daily life. Mobile phones and PDAs can be used in many application areas such as m-Commerce, m-Government and m-Health. The security of mobile transactions in such applications relies on accurate authentication of participants. Current mobile devices are capable of capturing reasonably good quality audio and video data, which enables the use of biometric based user authentication. Biometric based authentication can be used as an additional level of security to protect sensitive data stored on the mobile device and also when using external applications such as Internet banking. Due to their unobtrusive nature and because of the sensors that already exist on most mobile communication devices, the most suitable biometric features that can be used for user authentication are face, voice and signature. Current state-of-the-art methods used for face require computational resources that cannot be met by existing technology. This paper is concerned with face verification on such mobile communication devices. A wavelet-based face verification scheme have been developed by the authors and shown to perform as well as other most commonly used methods but with modest computational resources. In this paper we present a performance evaluation of our wavelet-based face verification using a new PDA audio-visual database that has been created for the European funded SecurePhone. Verification performance on the PDA database will be compared with our previous results based on other face databases. We shall demonstrate the efficiency of wavelet-based verification on the PDA.

6250-08, Session 2

On the use of AAM and a linear regression speaker transformation to break a GMM-based A/V speaker verification system

W. P. Karam, C. Mokbel, Univ. of Balamand (Lebanon); G. Chollet, Ctr. National de la Recherche Scientifique (France)

A GMM based audio visual speaker verification system is described and an Active Appearance Model with a linear regression speaker transformation system is used to evaluate the robustness of the verification. An Active Appearance Model (AAM) is used to automatically locate and track a speaker's face in a video recording. A Gaussian Mixture Model (GMM) based classifier (BECARS) is used for face verification. GMM training and testing is accomplished on DCT based extracted features of the detected faces. On the audio side, speech features are extracted and used for speaker verification with the GMM based classifier. Fusion of both audio and video modalities for audio visual speaker verification is compared with face verification and speaker verification systems.

To improve the robustness of the multimodal biometric identity verification system, an audio visual imposture system is envisioned. It consists of an automatic voice transformation technique that an impostor may use to assume the identity of an authorized client. Features of the transformed voice are then combined with the corresponding appearance features and fed into the GMM based system BECARS for training. This combined audio visual model is used for the detection of the absence of perfect audio / video synchronization in test video sequences that an impostor may have reproduced.

Experiments are being conducted on the BANCA database, with a prospect of experimenting on the newly developed PDAtabase developed within the scope of the SecurePhone project.

6250-09, Session 2

Comparison of weighting strategies in early and late fusion approaches to audio-visual person authentication

H. Sellahewa, N. Al-Jawad, Univ. of Buckingham (United Kingdom); A. C. Morris, D. Wu, J. Koreman, Univ. des Saarlandes (Germany); S. A. Jassim, Univ. of Buckingham (United Kingdom)

Person authentication can be strongly enhanced by the combination of different modalities. This is also true for the face and voice signals, which can be obtained with minimal inconvenience for the user. However, features from each modality can be combined at various different levels of processing and for face and voice signals the advantage of fusion depends strongly on the way they are combined. The aim of the work presented is to investigate the optimal strategy for combining voice and face modalities for signals of varying quality. The data are taken from the English Banca database, which contains audio-visual recordings in different conditions (controlled, degraded, adverse) and with both high and low quality microphones and cameras. Voice features use mel-frequency cepstral coefficients, while the face signal is parameterized using wavelet coefficients in certain subbands. Results are presented for both early (feature-level) and late (score-level) fusion. At each level different fixed and variable weightings are used, both to weight between frames within each modality and to weight between modalities, where weights are based on some measure of signal reliability, such as the accuracy of automatic face detection or the audio signal to noise ratio. In addition, the contribution to authentication of information from different areas of the face is explored to determine a regional weighting for the face coefficients.

6250-10, Session 2

Multimodal person authentication on a smartphone under realistic conditions

A. C. Morris, Univ. des Saarlandes (Germany); S. A. Jassim, H. Sellahewa, Univ. of Buckingham (United Kingdom); L. Allano, Institut National des Télécommunications (France); D. Wu, J. Koreman, Univ. des Saarlandes (Germany); S. Garcia-Salicetti, B. Ly-Van, B. Dorizzi, Institut National des Télécommunications (France)

Verification of a person's identity by the combination of more than one biometric trait strongly increases the robustness of person authentication in real applications. This is particularly the case in applications involving signals of degraded quality, as for person authentication on mobile platforms. The context of mobility generates degradations of input signals due to the variety of environments encountered (ambient noise, lighting variations,...), while the sensors' lower quality further contributes to decrease system performance. Our aim in this work is to combine traits from the three biometric modalities of speech, face and handwritten signature in a concrete application, performing non intrusive biometric verification on a personal mobile device (smartphone/PDA).

Most available biometric databases have been acquired in more or less controlled environments, which makes it difficult to predict performance in a real application. Our experiments are performed on a database acquired on a PDA as part of the SecurePhone project (IST-2002-506883 project "Secure Contracts Signed by Mobile Phone"). This database contains 60 virtual subjects balanced in gender and age. Virtual subjects are obtained in coupling audio-visual signals from a real English speaking subject with signatures from another subject captured on the touch screen of the PDA. Video data for the PDA database was recorded in 2 recording sessions separated by at least one week. Each session comprises 4 acquisition conditions: 2 indoor and 2 outdoor recordings (with in each case, a good and a degraded quality recordings). Handwritten signatures were captured in one session in realistic conditions. Different scenarios of matching between training and test conditions are tested to measure the resistance of various fusion systems to different types of variability and different amounts of enrolment data.

6250-11, Session 3

Secure steganography designed for mobile platforms

S. S. Agaian, R. C. Cherukuri, R. R. Sifuentes, Jr., The Univ. of Texas at San Antonio

Modern mobile devices are rapidly evolving into handheld computers capable of high resolution image capture, various multimedia applications, and world-wide telecommunications. Having access to this technology would allow organizations the ability of sophisticated and timely collaboration and synchronization. The presence of such critical transmissions over the airwaves manifests an inherent need of methods to ensure that the integrity and security of an intended message arrives uncompromised. The potential and widespread use of mobile devices makes them very receptive to the development of sophisticated image, audio, and video processing applications. Considering all factors, adaptive steganography would prove to be a valuable resource in the protection of sensitive material during the process of wireless transmission. Adaptive steganography is an approach for digitally embedding secure information selectively into another form of digital media and would serve as a valuable counterpart to already established cryptographic protocols. Since present methods cannot be directly applied, the algorithm in this paper is modified to acknowledge these mobile platform related problems:

1. Low embedding capacity in mobile devices due to fixed allowable image sizes on account of memory constraints.

2. Bit loss during wireless transmission due to channel noise and data compression.

3. Detection of steganography bearing images by widely available steganalysis software.

Applying an adaptive t-order statistical local characterization, the proposed algorithm is able to adaptively select the number of bits which are to be embedded in each pixel, thus increasing efficiency in capacity. Additionally, host pixels are selected in a manner that ensures robustness to the effects of wireless transmission. Secondly, we incorporate a Pn-sequence and matrix encoding based embedding technique to hide the information in the selected bits, thus increasing security. Finally, a histogram retention process and an evaluation measure based on the cover image and statistical analysis of the embedded image allow embedding of information in a manner which ensures soundness from multiple statistical aspects. Based on the results of simulated experiments, our method is shown to securely allow an increased amount of embedding capacity, simultaneously avoiding detection by varying steganalysis techniques.

6250-12, Session 3

A new JPEG-based steganographic algorithm for mobile devices

S. S. Agaian, R. C. Cherukuri, E. C. Schneider, G. B. White, The Univ. of Texas at San Antonio

Currently, cellular phones constitute a significant portion of the global telecommunications market. Modern cellular phones offer sophisticated features such as Internet access, on-board cameras, and expandable memory, which provide these devices with excellent multimedia capabilities. Robust security in mobile device communications is becoming a significant priority due to the high volume of cellular traffic, as well as the ability of these devices to transmit nearly all forms of data. One way to achieve this level of security is through steganographic methods. Existing steganographic algorithms which use JPEG-compressed images as a cover medium are not suitable for implementation on mobile devices due to three primary constraints. First, these algorithms are not robust to detection or extraction of hidden information. Second, camera phone images are of fixed size, which may result in low embedding capacity. The final constraint is the loss of steganographic information introduced in the saving and image conversion processes.

In this article, we propose a new algorithm for hiding information in JPEG-compressed images for mobile devices which can overcome the above

constraints. The proposed algorithm chooses discrete cosine transform coefficients for hiding information based on certain statistical properties, while taking into account the inherent constraints of mobile devices. The embedding process also uses a matrix encoding technique for enhancing the embedding capacity of the algorithm. Based on simulation results, the proposed method demonstrates an improved embedding capacity over existing algorithms, while maintaining a high robustness to detection by various steganalysis techniques.

6250-13, Session 3

On mobile wireless ad hoc IP video transports

M. I. Kazantzidis, Broadata Communications, Inc.

Multimedia transports in wireless, ad-hoc, multi-hop or mobile networks must be capable of obtaining information about the network and adaptively tune sending and encoding parameters to the network response. Obtaining meaningful metrics to guide a stable congestion control mechanism in the transport (i.e. passive, simple, end-to-end and network technology independent) is a complex problem. Equally difficult is obtaining a reliable QoS metrics that agrees with user perception in a client/server or distributed environment. Existing metrics, objective or subjective, are commonly used after or before to test or report on a transmission and require access to both original and transmitted frames. In this paper, we propose that an efficient and successful video delivery and the optimization of overall network QoS requires innovation in a) a direct measurement of available and bottleneck capacity for its congestion control and b) a meaningful subjective QoS metric that is dynamically reported to video sender. Once these are in place, a binomial -stable, fair and TCP friendly- algorithm can be used to determine the sending rate and other packet video parameters. An adaptive mpeg codec can then continually test and fit its parameters and temporal-spatial data-error control balance using the perceived QoS dynamic feedback. We suggest a new measurement based on a packet dispersion technique that is independent of underlying network mechanisms. We then propose a binomial control based on direct measurements. We implement a QoS metric that is known to agree with user perception (MPQM) in a client/server, distributed environment by using predetermined table lookups and characterization of video content. We then present simulation experiments that show the comparative performance of these techniques single and multi-hop mobile networks, were adaptive video delivery is most challenging.

6250-14, Session 3

Enhancement of node connectivity for a secure mobile wireless network

X. Shi, F. Li, C. R. Adams, Univ. of Buckingham (United Kingdom)

For secure mobile wireless networks that their topologies are changed dynamically in insecure environments, mobile users need to keep in contact with each other for the purpose of user authentications. For instance, the network formed by a group of soldiers equipped with wireless devices in a batter field. Maintaining a high connectivity is crucial in such networks in order to make scattered individuals to be authenticated. To establish connections, different mobile ad hoc network routing protocols have been developed. However, many researches have shown that these protocols are incapable of maintaining high connectivity when the node density is lower in the network. This paper proposes a mechanism to enhance the node connectivity, which is specifically effective for mobile networks with lower node densities. It selects some nodes with larger transmission power as strategic nodes to assistant establishing connection with remote nodes, which are unable to connect to otherwise. The strategic nodes have the ability to connect to each other. Whenever a remote mobile node has a request to connect to another remote mobile node, the strategic nodes functions as a normal mobile node and may forward the request to the desired remote destination node. The mechanism is simulated in different scenarios with various node densities, and the results shows that the node connectivity is generally enhanced with the benefit of lower node density network gaining significant improvement.

6250-15, Session 3

Robust image transmission over MIMO space-time coded wireless systems

D. Song, C. W. Chen, Florida Institute of Technology

Multimedia communications over mobile wireless networks have attracted significant research attention recently. However, the time-varying characteristics of wireless channels have been a major challenge for reliable end-to-end multimedia communication. In this paper, we propose a robust image transmission scheme for broadband wireless systems over time-varying multipath fading channel with no feedback. The robustness of the proposed system is achieved by integrating error resilient source coding strategy with channel coding and coherent spatial diversity characterized by orthogonal frequency division multiplexing (OFDM).

The embedded encoding is able to achieve high compression efficiency, but may cause catastrophic error propagation if an error occurs at the beginning of the embedded bitstream. Therefore, we develop a multiple bitstream scheme that converts the original single embedded bitstream to multiple embedded bitstreams so that possible error propagation is limited to much smaller segments of multiple bitstreams. Each bitstream is individually encoded using the well-known SPIHT algorithm.

Transmission errors over wireless channels range from a single bit errors to bursty bit errors during deep fading periods. These widely varying error conditions over time-varying wireless systems limit the effectiveness of channels coding, since it is difficult to design an appropriate channels coders when there is no feedback. For a given channel coding scheme, the error protection may be inadequate when the channel is in deep fading while may be wasted when the channel is in good condition.

The system capacity can be significantly improved if multiple transmit and receive antennas are used to form multi-input multi-output (MIMO) channels. It has been proven that, compared with a single-input single-output (SISO) system with flat Rayleigh fading or narrowband channels, a MIMO system can improve the capacity by a factor equivalent to the minimum number of transmit and receive antennas. For wideband transmission of multimedia data, the inter-symbol interference (ISI) is another challenge issue where the delay spread of multipath may be higher than symbol rate. The OFDM scheme is one of the most promising techniques to mitigate the ISI by dividing the channel into many narrow parallel subchannels, thereby increasing the symbol duration and reducing or eliminating the ISI caused by the multipath.

To maximize the robustness of image transmission over mobile wireless channels, we adopt an integrated approach to combine the error resilient image coding with transmit diversity technique, namely space-time block codes (STBC) and OFDM, to achieve the desired robustness of image transmission. By combining these two advanced techniques, the frequency selective fading effects in broadband wireless channels can be significantly reduced and the subchannels in OFDM systems would approach Gaussian noisy channels when the diversity gain is large. The system performance of image transmission can be improved in terms of throughput and channel coding efficiency.

Then, rate compatible punctured convolution (RCPC) channel codes as unequal error protection (UEP) method are adopted both to combat the mitigated BER by transmit diversity with OFDM and to maximize end-to-end quality based on the bit error sensitivity of different bit planes. The analysis and experimental results demonstrate that each of these components has contributed to the overall robustness of the proposed image transmission over mobile wireless systems with time-varying multipath fading.

6250-16, Session 4

Privacy enabling technology for video surveillance

F. Dufaux, M. Ouaret, Y. Abdeljaoued, École Polytechnique Fédérale de Lausanne (Switzerland) and Emitall Surveillance SA (Switzerland); A. Navarro, Emitall S.A. (Switzerland); T. Ebrahimi, École Polytechnique Fédérale de Lausanne (Switzerland) and

Emitall Surveillance SA (Switzerland)

In this paper, we describe an efficient, flexible and cost-effective smart video surveillance system. One of the most important feature of the system is a new privacy enabling technology. Regions of interest in the scene are identified and scrambled. As a result, the scene is visible but people under surveillance cannot be identified.

More specifically, the system is composed of several simple wired or wireless surveillance cameras. The latter case is especially appealing as it makes it very easy and cost effective to deploy and relocate cameras as the surveillance needs evolve. The following video processing steps are then carried out on a surveillance server. First, a video analysis module identifies Regions of Interest (ROI). This can be efficiently achieved with techniques such as change detection or face detection. In case of intrusion detection, the system may take appropriate actions, e.g. trigger an alarm, send SMS or MMS and store the corresponding sequences for archiving. The video is then compressed for efficient storage and transmission. Previously identified ROIs are encoded with higher quality. Next, scrambling is applied to the ROIs. The scrambling can be adapted to generate from mere fuzziness to complete noise. As a result, people in the scene are not recognizable while the remaining of the scene is visible, successfully addressing the loss of privacy issue. The resulting codestream is digitally signed in order to guarantee data integrity. Finally, heterogeneous clients, such as desktop and laptop PCs, PDAs and cell phones, can access the system through a gateway in order to view live or recorded videos.

6250-17, Session 4

Object segmentation by fusion of multiclues in stereo sequences

P. An, Shanghai Univ. (China); Z. Zhang, Shanghai Univ. (China) and Key Lab. of Advanced Displays and System Application, Ministry of Education (China)

Among many image segmentation algorithms proposed, motion information has been widely accepted as a crucial cue. However, in the case of stereo video, it is possible to use additional knowledge, the depth or disparity information to obtain final segments more precisely since video objects are usually consisted of regions belonging to the same depth plane. Apart from the two clues of motion and depth, edges and color information is also useful for classifying the scene. In this paper, an algorithm for object segmentation from stereo sequences based on fusion of multi-clues of edge, disparity, motion and color is proposed. Experimental results show this algorithm is effective for complex scene segmentation that usually is difficult to do in the case of monocular video. Firstly, we estimate the disparity field. As efficient search method, an improved genetic algorithm (GA) based on image edge is applied to find the best matching pair. Disparity field with clear contour can be obtained after disparity estimation. Then, the morphological operators are performed on the given disparity field to obtain coarse objects segments. “Split and merge” process is applied to extract the objects regions, and “erosion and dilation” process is to fill some small inner holes in the target regions or smooth the discontinuous regions. The segmentation results of disparity field approximate to semantic objects although introduce errors on object boundaries with depth jumps, but are reliable within objects. The motion and color information are fused to eliminate the errors as follows. The motion information can be estimated by using inter-frame change detection. Different object boundaries can be articulated according to the motion vectors scopes. Also, the pixels with similar color may belong to the same objects for color jumps usually occur at the object boundaries. The segmentation errors at the object boundaries especially at the overlapped parts are corrected by fusion of the motion and color information.

6250-18, Session 4

Forensic analysis of signals processed by CODECs in mobile applications for hardware identification

O. Moreira-Tamayo, The Univ. of Texas at San Antonio

This paper presents an approach for the identification of the hardware used in the codification or decodification of signals. The objective is to determine if a sample signal was processed or not by a specific piece of hardware. The approach proposed is based in the identification of the unique imperfections that the Codec’s A/D or D/A converter has.

Common data converters specifications for mobile applications include Signal to Noise ratios and Integral Non-Linearity and Differential Non-Linearity as measures of imperfection of the transfer characteristics of the converter. These parameters are directly proportional to the component matching and are proportional to the area used for the converter in the integrated circuit. Since minimization of the area is pursued to reduce cost, the imperfections present are tolerated if they are below certain specifications.

The approach proposed consists of first searching in the signal for indications of the type of architecture used for the converter, e.g., Flash or Sigma-Delta. In a second step we look for specifications such as resolution, SNR, etc. As a third step we look of the unique imperfections or the transfer characteristic such as bit to bit, or LSB to MSB mismatch in Flash converters, or the tones typically present below noise floor and the noise shaping for Sigma-Delta converters. Further verification can be performed if a suspected piece of hardware is available. A test signal is applied to the hardware and then analyzed to see if it matches the same patterns present in the initial signal.

6250-20, Session 4

Content-based video indexing and searching with wavelet transformation

F. Stumpf, N. Al-Jawad, H. Du, S. A. Jassim, Univ. of Buckingham (United Kingdom)

Video-databases are in increasing demand in various applications such as homeland security, law enforcement, road traffic control, fraud detection, etc. As computers with high capacity storage and fast processing speed are readily available, it is affordable for increasing numbers of organisations to store a large amount of video materials in databases. However, effective searching for a specific video remains a major challenge. Searching by description of a video, which involves indexing videos by their property descriptions entered manually, is no longer satisfactory. The ideal strategy of video indexing and searching must be based on features that are automatically extracted from the contents of video files. Such a search strategy is similarity-based in nature.

In this paper, we are proposing a content-based video indexing and searching approach using wavelet transformation on greyscale video’s frames. The statistical features from each non-LL sub-band have been extracted. The average and standard deviation (STDEV) of all the STDEVs for each non-LL sub-band across all frames are calculated. The results are collectively used as the “fingerprint” of the video.

Initial experiments we have conducted show the uniqueness of the fingerprint to each video. To enhance searching result for similar videos, histogram-equalization and gamma-correction might be applied. The potential advantages of our approach include simplicity of the approach and relative small size of the extract features per video. We believe that the fingerprint is related to measures of similarity of videos, which may lead to effective clustering and indexing of a large number of similar videos.

6250-24, Session 4

A logarithmic measure of image enhancement

E. J. Wharton, Tufts Univ.; S. S. Agaian, The Univ. of Texas at San Antonio; K. A. Panetta, Tufts Univ.

Performance measures of image enhancement are traditionally subjective and don't quantify the improvement made by the algorithm. Even today, enhancement performance is judged by human observation for many applications. The first quantitative measures introduced were based upon image contrast as a means to measure the image quality, and later incorporated edge information or the well known entropy concept as well. Agaian's AWC measure was the first practical use of Weber's law based upon contrast to measure image enhancement, and has since been developed greatly to include the entropy concept and other definitions of contrast. In this paper, we investigate a measure of image enhancement based upon entropy and the Michelson contrast measure.

Traditional enhancement measures have had some problems due to the simple measure of contrast and entropy. This gives preference to images with a large amount of contrast and very little useful information, such as enhanced images with a large amount of static, as opposed to good enhancements when using algorithms that require careful selection of parameters. These shortcomings led to the investigation of the AMEE measure based on entropy.

The AMEE based on entropy uses the Michelson contrast, which is better suited for real images because it assumes a periodic pattern as opposed to a small test target at the center of a large uniform background. In this paper, we demonstrate the logarithmic AMEE measure and show how utilizing logarithmic based addition, subtraction, and multiplication provides better results than previously used measures.

Our results show that by combining the AMEE measure with logarithmic arithmetic functions, we achieve a better measure of enhancement better suited for a wide range of images from standard test images to cell phone images.

6250-27, Session 4

Wireless just-in-time training of mobile first responders

C. Bandera, BanDeMar Networks

Skilled Service Personnel (SSP) support emergency response organizations during an emergency incident, and include laborers, operating engineers, carpenters, ironworkers, sanitation workers and utility workers. SSP called to an emergency incident rarely have recent detailed training on the chemical, biological, radiological, nuclear and/or explosives agents or the personal protection equipment relevant to the incident. This increases personal risk to the SSP and mission risk at the incident site. We present a just-in-time training (JITT) system made possible by advances in distance learning and cellular telephony. In addition to the conventional mandatory training at regularly scheduled instructional events, skilled support personnel in route to an emergency incident will have secure access to short (<5 minutes) training modules specific to the incident incorporating streaming audio, video, interactive simulations, graphics, animation, and assessment designed for the user interface of most current cell phones. Challenges include ubiquitous operation across current cell phones and wireless service providers, and integration with the incident management system. We also present the repurposing to this JITT system of OSHA course #7600 Disaster Site Worker Course and its pilot deployment through the New Jersey Center for Public Health Preparedness.

6250-19, Poster Session

On a symmetry principle for information processing

E. H. Feria, College of Staten Island/CUNY

Recently a novel Compression-Designs methodology has been offered for the design of efficient intelligent systems. A remarkable result derived was that in the presence of highly compressed intelligence, complexity compressed intelligence processors (CIPs) yielded significantly better global system performance than complexity uncompressed intelligence processors (UIPs). In this paper it is shown via a real-world knowledge-aided (KA) airborne moving target indicator (AMTI) radar system subjected to severely taxing disturbances that a "symmetry principle of information processing" guides this result. A fundamental consequence of this discovery is that an appropriately modified sample matrix inverse (SMI) algorithm, NOT KA, emulates the high radar performance achieved with the more complex KA-AMTI system. It is possible that Compression-Designs in conjunction with the symmetry principle for information processing may be applied to cell phone data bases.

6250-21, Poster Session

The effects of malicious nodes on performance of mobile ad hoc networks

F. Li, X. Shi, S. A. Jassim, C. R. Adams, Univ. of Buckingham (United Kingdom)

In mobile wireless ad hoc networks that the networks topologies are dynamically changing, every mobile node can receive messages from its neighbors and can be contacted by all other nodes in the networks. This poses a great danger to network security if some nodes misbehave. The immediate concern about the security in this type of networks is how to protect the networks and the mobile nodes from attacks by malicious nodes that are in the networks. Such attacks have significant impact on the delivery of high volume real multimedia content. For example, when transmitting biometric data, authentication is undermined by such attacks. The kind of effects will be particularly serious in conflict or disaster zones.

This paper presents simulation results of ad hoc wireless network performance in the presence of malicious nodes. The characteristics of malicious nodes are defined, implemented and simulated. The network is simulated in a variety of scenarios including different number of nodes, different mobile velocities, and with different number of malicious nodes. We will demonstrate that network performance deteriorates significantly in the presence of malicious nodes and the level of deterioration depends on the defined misbehaving characteristics of these nodes. We use a number of criteria to measure network performance such as successful packet delivery ratio, average path length, route setting up time and packet delivery time. It is expected that a mechanism of detecting and isolating malicious nodes from ad hoc networks can be defined based on the results presented in this paper.

6250-22, Poster Session

An imaging toolbox for smart phone applications

A. Panchul, D. Bhupathiraju, S. S. Agaian, D. Akopian, The Univ. of Texas at San Antonio

The paper presents a Digital Image Processing educational toolbox for cellular phones. It is intended for users studying imaging algorithms and allows the processing of real images taken by the camera phones. For example, users are able to analyze the images and selected regions of interest using different transforms including Discrete Fourier, Hartley, and Cosine Transforms. One can apply different filters such as median and moving average. Simple image enhancement techniques are also included in the toolbox. A handy user interface allows a suitable browsing through the images and operators. The toolbox is designed to be expandable and more operations will be included in the future.

The toolbox is implemented using Series 60 Platform SDK for Symbian OS, for C++. It allows developers to quickly and efficiently run and test applications for devices that are compatible with the Series 60 Platform. The algorithms are first implemented on Series 60 Platform device emulator on the PC and then installed on the cell phone.

6250-25, Poster Session

Secure image communication for network applications

S. Lian, France Telecom R&D Beijing (China)

A secure image transmission scheme based on JPEG2000 is proposed in this paper, which combines encryption process with encoding process and is suitable for real-time applications over network. In this scheme, the sensitive data are self-authenticated, then partial-encrypted during compression process, and the compressed data are encrypted by light-weight encryption algorithm combined with error-correction codec. The self-authentication process can detect malicious tamper or great transmission errors. Thus, the encryption process obtains suitable tradeoff between security and time-efficiency through encrypting data adaptively, and keeps the original system's error-robustness unchanged. The decryption process is symmetric to the encryption process. Experimental results show that this scheme obtains high perception security and time efficiency, and is suitable for secure image transmission over network.

6250-26, Poster Session

Directional edge detection using the logical transform for binary and grayscale images

E. E. Danahy, Tufts Univ.; S. S. Agaian, The Univ. of Texas at San Antonio; K. A. Panetta, Tufts Univ.

Edge detection, the process of determining edge pixels within an image, is an important task in feature-based image processing and within scene analysis systems. For example, military applications involving machine vision tasks such as object recognition and motion analysis often rely on the accurate identification of edges. Further, security applications including data coding, data hiding, and watermarking also benefit from improved directional edge detection capabilities.

There are several general edge detection methods available employing a variety of techniques, from linear filtering, to local orientation analysis, to the fitting of analytical models onto the image data. This paper presents a new algorithm for the identification of edges in binary and grayscale images through the decomposition of the signal via a logical transform. A sliding window is employed to analyze portions of the data individually, and edges contained within are classified based on the sum of primary implicants representation of the pixels. Edges are separately deemed to be horizontal, vertical or diagonal, and a resulting output combination of these three types is constructed.

The window size used in the algorithm is varied and the effect of this on the detection ability is examined. Small sized windows are more sensitive to edge boundaries, but the performance often affected by noise. Larger window sizes, while not as influenced by small amounts of noise, can result in a possible loss of finer details.

The performance of the proposed algorithm is compared to output from several of the current leading edge detection methods (Sobel, Laplacian, Canny). Pratt's figure of merit measurement is used to quantitatively compare the methods, by performing edge detection on synthetic images where edge locations are known. The effectiveness of the proposed method is also tested on real-world images and the resulting edge maps generated by the various methods compared visually.

The robustness of the algorithm is further tested under the presence of noise. Various types of noise can be introduced into the image either during the acquisition or during the transmission and storage. Using initial edge maps generated by the algorithm run on clean data as a benchmark, it is possible to mathematically analyze (again with Pratt's measurement) the resulting output as noise is added to the input.