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Abstract Proceedings

Signal and Imaging Sciences Conference

CASIS 2007

Thursday, November 15, 2007
Friday, November 16, 2007

Sponsored by
Lawrence Livermore National Laboratory
Engineering Directorate

Center for Advanced Signal and Image Sciences (CASIS)
Steve Azevedo, Randy Roberts, Co-Directors
http://casis.llnl.gov

Center for Advanced Signal and Image Sciences

ENGINEERING

WELCOME

The fore-runner to the CASIS Conference was originally called the "Imaging Workshop", and it was organized at LLNL by Jerry Krammen and Mark Lachapell in 1987. They were inspired by the observation that vendors or collaborators outside our fences sometimes knew more about the work in various laboratory experiments than they did — often addressing the same technical problems. A way to share engineering issues and insights among laboratory colleagues was needed, they thought. Rick Twogood of the Electronics Engineering Department supported them in the idea and helped secure funds to make it a success.

Several infrequent workshops were held over the next few years until Jim Candy formed the Center for Advanced Signal and Image Sciences (CASIS) in 1994 and made the CASIS Workshop (now CASIS Conference) a yearly event. While it is the 14th annual CASIS event, we want to acknowledge the foresight of those people who started the idea 20 years ago. The need for this type of conference is still strong and the support from Engineering and the Laboratory continues. This year as usual we are pleased to bring you an impressive array of presentations in the areas of signal processing, imaging, communications, controls, along with associated fields of mathematics, statistics, and computing sciences.

We extend a welcome to keynote speaker Professor Jitendra Malik of the EECS Department at the University of California, Berkeley. He has worked extensively in the image processing field, and will talk with us about his recent work in object recognition in images and video. His presentation, like those of our distinguished group of former keynote speakers, will be videotaped and made available for check out from the CASIS staff.

We are also fortunate to have two Principal Associate Directors who will be addressing CASIS this year. Dr. Ed Moses, Principal AD for the National Ignition Facility (NIF) and Photon Science, will give an overview and status of the NIF with an emphasis on the enormous data processing challenges there. For the last two years, CASIS has been held in a NIF Auditorium, and it is much appreciated. Also, John Doesburg, the new Principal AD for Global Security, will speak about the needs in the security arena.

On behalf of the entire CASIS staff and the LLNL Engineering Directorate, we want to welcome you to this Fourteenth Annual Signal and Image Sciences Conference. We acknowledge the Engineering Directorate — especially Steve Patterson, AD, and Greg Suski, DAD/S&T — for their generous support over the years. They view these disciplines as critically important to virtually all laboratory programs. We also thank our outstanding administrative staff of Vickie Abreu, Leslie Alfonso and Deana Eshpeter. (Even though Deana retired this year, she came back to see you all again!) Be sure to thank them personally for their extra work in handling the hospitality this year. Many thanks as well go to the Engineering Art & Edit Team of Debbie Ortega, Irene Chan, and Kathy McCullough. We could not have put on this event without them. Thank you all!

Please make the most of the next two days of presentations. This is a perfect time to learn about your colleagues' work, and exchange ideas openly with the participating scientists and engineers. We ask you to fill in and return the feedback/survey form so we can make the CASIS Conference even better next year!

Stephen Azevedo and Randy Roberts
C.A.S.I.S. Co-Directors
http://casis.llnl.gov

Signal and Imaging Sciences Conference

Keynote Speakers Over the Years

Year	Speaker	Title
1997	Dr. Donald Kania	Overview of the Advanced Microtechnology Program
1998	Dr. Anthony Devaney, Northeastern University	Diffraction Tomography
	Dr. Ronald Bracewell, Stanford University	Detection of Nonsolar Planets by Spinning Infrared Interferometer
1999	Dr. Bernard Widrow, Stanford University	A Microphone Array for Hearing Aids
	Dr. Avi Kak, Purdue University	A Retrospective on Computer Vision Research
2000	Prof. Simon Haykin, McMaster University	Adaptive Systems for Signal Processing
	Dr. Christian Pichot, University of Nice	Subsurface Tomography Using Ultra-Wide Band Systems
2001	Dr. James Greenleaf, Mayo Foundation	Vibro-Scoustography: Ultrasonic Imaging Without Speckle
	Prof. A. Paulraj, Stanford University	Multiple Input - Multiple Output (MIMO) Wireless: The New Frontier
2002	Dr. Alan Witten, University of Oklahoma	Expedition Adventure: Using Geophysics to Find Dinosaurs, Pirate Ships and Cavemen
	Dr. Leon Cohen, University of New York	Time-Frequency Description of Signals
2003	Dr. Thomas Budinger, UC Berkeley	Recent Advancements in Medical Imaging
2004	Prof. Alan Oppenheim, MIT	Things My Mother Never Told Me (About Signal Processing)
	Prof. James McClellan, Georgia Tech	Array Signal Processing for Locating Buried Objects and Tracking Moving Targets
2005	Prof. James Flanagan, Rutgers University	Natural Interfaces for Information Systems
2006	Prof. Sanjit Mitra, University of Southern California	Recent Research Results in Image and Video Processing
	Dr. James Candy, LLNL, UC Santa Barbara	A Bayesian Approach to Nonlinear Statistical Signal Processing

CASIS

Center for Advanced Signal and Image Sciences

Center for Advanced Signal and Image Sciences

AGENDA

Signal and Imaging Sciences Conference

CASIS is a Conference for LLNL, and others to share accomplishments, ideas and areas of need in the Signal, Imaging and Communications Sciences

November 15 – 16, 2007

Sponsored by the LLNL Engineering Directorate and the Center for Advanced Signal and Image Sciences (CASIS)

Center for Advanced Signal and Image Sciences

ENGINEERING

AGENDA
Signal and Image Sciences Conference
Center for Advanced Signal and Image Sciences
Lawrence Livermore National Laboratory

THURSDAY, NOVEMBER 15, 2007 BUILDING 482 AUDITORIUM

8:00 AM Registration, Distribution of Proceedings and Continental Breakfast
8:45 AM Opening Remarks, Introductions ..... Stephen Azevedo, CASIS Co-Director
8:55 AM Welcome from Engineering ..... Dr. Steven Patterson, AD Engineering
9:00 AM Keynote Address, Recognizing Objects and Actions in Images and Video ..... Professor Jitendra Malik, UC Berkeley

10:00AM MORNING BREAK

Imaging Technology
Session Chair: John Chang

10:30 AM Imaging Without Lenses: X-Ray Snapshots with Nanometer Spatial and Femtosecond Temporal Resolution ..... Anton Barty
10:45 AM Segmentation of Three-dimensional Retinal Image Data ..... Alfred R. Fuller
11:00 AM Overview of Ultrawideband Microwave Space-Time Beamforming for Hyperthermia Treatment of Breast Cancer ..... Essex Bond
11:15 AM Increased Data per Dollar High-Speed Imaging ..... Derek Decker
11:30 AM Auto-Tuning of PID Controllers via Extremum Seeking ..... Nick J. Killingsworth
11:45 AM Polygon Matching in Overhead Images: Particle Tracks through Fields of Corners and Pixel Gradients ..... Siddharth Manay

12:00PM LUNCH BREAK

Radiation Detection
Session Chair: Simon Labov

1:00 PM Signal Processing Challenges for Radiation Detection ..... Simon Labov
1:15 PM Gamma-Ray Detector Resolution Study ..... Karl E. Nelson
1:30 PM A Bayesian Sequential Processor Approach to Spectroscopic Portal System Decisions ..... Douglas Manatt
1:45 PM A Comparison of Signal Processing and Classification Algorithms for Detecting the Presence of a Threatening Radiation Source ..... Barry Chen
2:00 PM Contextually Aware Nuclear Evaluation System ..... Simon Labov
2:15 PM Image Analysis of Radiographic Scans for Detection of Threats in Cargo Containers ..... Wilbert McClay
2:30 PM Time Reversal Based Ultra-wideband Radio Frequency Tags ..... Faranak Nekoogar

2:45 PM AFTERNOON BREAK

Adaptive Optics
Session Chair: Lisa A. Poyneer

3:00 PM Performance of a MEMS-based AO-OCT System ..... Julia W. Evans
3:15 PM Compact Adaptive Optics Scanning Laser Ophthalmoscope ..... Diana C. Chen
3:30 PM Kalman Filtering for Predictive Wavefront Control in Adaptive Optics ..... Lisa A. Poyneer
3:45 PM Iterative Shack-Hartmann Wave-Front Sensing for Open-Loop Metrology Applications ..... Kevin Baker

4:00 PM ADJOURN

AGENDA
Signal and Image Sciences Conference

Center for Advanced Signal and Image Sciences
Lawrence Livermore National Laboratory

FRIDAY, NOVEMBER 16, 2007 BUILDING 482 AUDITORIUM

8:00 AM Registration, Distribution of Proceedings and Continental Breakfast
8:50 AM Opening Remarks, Introductions ..... Randy Roberts, CASIS Co-Director
9:00 AM National Ignition Facility Overview and Status ..... Dr. Ed Moses, Principal Associate Director, NIF & Photon Science

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National Ignition Facility (NIF)
Session Chair: Ric Beeler

9:30 AM Final Optics Damage Inspection for the National Ignition Facility ..... Alan Conder
9:45 AM Automated Inspection for NIF Final Optics ..... Judy Liebman
10:00 AM Avatar Machine Learning for NIF Optics Inspection Analysis ..... Laura Kegelmeyer
10:15 AM Why and How to Exploit OOB Validation for Ensemble Size ..... Philip Kegelmeyer

10:30 AM MORNING BREAK

10:45 AM Automatic Alignment System for the National Ignition Facility ..... Karl Wihelmsen
11:00 AM What Can We Learn from the Correlation Shape? ..... Abdul Awwal
11:15 AM Application of Linear Systems Signal Processing Techniques for Remote Calibration of LVDT Systems ..... David Bloom
11:30 AM NIF VRT Pinhole Alignment Algorithm ..... Joshua Gordon

11:45 AM LUNCH BREAK

1:00 PM Global Security Needs and Strategies ..... John C. Doesburg, Principal Associate Director, Global Security

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Terahertz Imaging
Session Chair: Farid Dowla

1:15 PM Standoff Detection of High-Explosives Using THz Imaging Spectroscopy ..... Farid Dowla
1:40 PM Terahertz Spectroscopic Imaging for First Responders ..... Michael Burke

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Nondestructive Evaluation
Session Chair: Harry E. Martz, Jr.

1:55 PM Nondestructive Evaluation Technologies to Defend the Homeland ..... Harry E. Martz, Jr.
2:15 PM Ultrasonic Determination of HE Density ..... Robert Huber
2:30 PM Xradia MicroXCT: A 3D X-Ray Computed Tomography System ..... John Sain
2:45 PM Model-Based Algorithms for Detecting Cable Damage from Time-Domain Reflectometry Measurements ..... Grace A. Clark
3:00 PM Development of an Acoustic Backpropagation Method to Detect and Localize Changes in an Instrumented Structure ..... David H. Chambers

3:15 PM ADJOURN

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Keynote Speaker

Professor Jitendra Malik
University of California Berkeley

Center for Advanced Signal and Image Sciences

Recognizing Objects and Actions in Images and Video

Professor Jitendra Malik
Electrical Engineering and Computer Sciences
UC Berkeley

The object recognition problem is that of finding instances of object classes in an image or video sequence: faces, giraffes, the digit 5, chairs etc. This has to be accomplished while allowing for intra-class variation, as well as changes in illumination and viewpoint. Dr. Malik's group has developed a theory of object recognition by measuring shape similarity, using point correspondences based on robust relational descriptors: "shape contexts" and "geometric blur templates".
He will show results on a variety of 2D and 3D recognition problems. The action recognition problem is that of finding instances of actions in video sequences – run, jump, kick, etc. –all the while allowing for variation in the person performing the action, clothing, illumination and viewpoint.
This talk is based on joint work; please visit http://http.cs.berkeley.edu/projects/vision/vision_group.html for pointers to publications.

Professor Jitendra Malik received the B.Tech degree in Electrical Engineering from the Indian Institute of Technology, Kanpur, 1980 and a Ph.D. in Computer Science from Stanford University, 1985. In January 1986, he joined the UC Berkeley where he is currently the Arthur J. Chick Professor in the Computer Science Division. He is also on the faculty of the Cognitive Science and Vision Science groups. During 2002-2004 he served as the Chair of the Computer Science Division and during 2004-2006 as the Department Chair of EECS.

He received the gold medal for the best graduating student in Electrical Engineering from IIT Kanpur in 1980, a Presidential Young Investigator Award in 1989, and the Rosenbaum fellowship for the Computer Vision Programme at the Newton Institute of Mathematical Sciences, University of Cambridge in 1993. He received the Diane S. McEntyre Award for Excellence in Teaching from the Computer Science Division, University of California at Berkeley, in 2000. He was awarded a Miller Research Professorship in 2001. He is a fellow of the IEEE.

Imaging Technology

John Chang, Session Chair

Center for Advanced Signal and Image Sciences

Imaging Without Lenses: X-Ray Snapshots with Nanometer Spatial and Femtosecond Temporal Resolution

Anton Barty
UCRL-ABS-235770

The ultrafast pulses from X-ray free-electron lasers are ushering in extraordinary new capabilities in X-ray imaging, including potentially the imaging of isolated objects at near-atomic resolution. Of particular interest is the potential to determine the structures of proteins, viruses and macromolecules that cannot be crystallized. Radiation damage limits are overcome by obtaining coherent diffraction patterns using pulses that are shorter than the timescales for radiation-induced changes to occur in the object at available resolution length scales. The X-ray probe is sufficiently intense that the specimen may be be completely destroyed by the pulse, but that destruction will only happen after the X-ray pulse has passed through the object. The scattering pattern from the object will therefore give structural information about the undamaged object, with simultaneous nanometer spatial and femtosecond temporal resolution.

A collaboration between LLNL, Uppsala University, SLAC, DESY, and LBNL has been following a program of research at the FLASH soft-X-ray FEL at DESY, Hamburg, to develop the experimental methods for FEL diffractive imaging. We have reconstructed images from single-pulse ultrafast diffraction patterns that show no evidence of the effects of the FEL pulse on the structure even though the object was completely vaporized by the intense pulse. We also performed quantitative measurements of the explosion of test particles in the focused FEL pulse by recording their transient diffraction patterns. No motion occurred during the pulse and we followed the evolution of the explosion with a novel holographic time-resolved technique. Our results confirm the basic principles of flash imaging and lend great confidence to achieving molecular imaging at future short-wavelength X-ray FELs.

Segmentation of Three-dimensional Retinal Image Data

Alfred R. Fuller, Robert J. Zawadzki, Stacey Choi, David F. Wiley, John S. Werner, and Bernd Hamann
UCRL-ABS-235656

We have combined methods from volume visualization, data analysis and image processing to support better diagnosis and treatment of human retinal diseases. Many diseases can be identified by abnormalities in the thicknesses of various retinal layers captured using optical coherence tomography (OCT). We used a support vector machine (SVM) to perform semi-automatic segmentation of retinal layers for subsequent analysis including a comparison of layer thicknesses to known healthy parameters. We have extended and generalized an older SVM approach to support better performance in a clinical setting through performance enhancements and graceful handling of inherent noise in OCT data by considering statistical characteristics at multiple levels of resolution. The addition of the multi-resolution hierarchy extends the SVM to have a more "global awareness." A feature, such as a retinal layer, can therefore be modeled within the SVM as a combination of statistical characteristics across all levels; thus capturing high- and low-frequency information. We have compared our semi-automatically generated segmentations to manually segmented layers for verification purposes. Our main goals were to provide a tool that could (i) be used in a clinical setting; (ii) operate on noisy OCT data; and (iii) isolate individual or multiple retinal layers in both healthy and disease cases that contain structural deformities.

Overview of Ultrawideband Microwave Space-Time Beamforming for Hyperthermia Treatment of Breast Cancer

Essex Bond*, Mark Converse, Susan Hagness, and Barry Van Veen
University of Wisconsin – Madison, *Current LLNL Employee

Ultrawideband (UWB) space-time beamforming techniques are potentially powerful tools for high-power focusing of microwave energy for hyperthermia treatment of breast cancer. Hyperthermia is a well-known thermal therapy wherein the cytotoxic effects of elevated temperatures are induced to achieve cell-death or render the cells more vulnerable to ionizing radiation and/or chemical toxins. Although clinical studies have shown local electromagnetic hyperthermia treatment of cancer to be an effective adjunct to radiation and chemotherapy, difficulties still remain with achieving a tight focus on malignant tissue and not heating healthy tissue. By solving the concentration ratio problem, we demonstrate the theoretical feasibility of the UWB approach using 2-D electromagnetic and thermal simulations of realistic numerical breast phantoms implemented using the finite-difference time-domain method. In particular, we compare UWB and narrowband (NB) focusing of microwave energy and show that UWB focusing consistently produces the necessary temperature gradients required for effective hyperthermia treatment while preserving normal physiological temperatures throughout larger regions of normal tissue relative to NB focusing.

Increased Data per Dollar High-Speed Imaging

Derek Decker
UCRL-PRES-228465

New methods are being explored and old methods revisited for acquiring a sequence of images of brief events. More and better data is needed to improve our understand of the movement of materials under shocked conditions. Jet formation of explosively driven shaped charges is one example where high-speed images can help designers build better systems comprised of high explosives. One of the methods presented will include movies of HE shots in LLNL's High Explosives Application Facility (HEAF).

Auto-Tuning of PID Controllers Via Extremum Seeking

Nick J. Killingsworth, Salvador M. Aceves, Daniel L. Flowers, and Miroslav Krstic

UCRL-ABS-235149

The proportional-integral-derivative (PID) controller is widely used in the process industry, but to various degrees of effectiveness because it is sometimes poorly tuned. The goal of this work is to present a method using extremum seeking (ES) to tune the PID parameters such that optimal performance is achieved. ES is a non-model based tuning method that performs an on-line parameter search such that a cost function is minimized; in this case the cost function is representative of the controller's performance. ES is not based on linear systems theory, thus the method is independent of whether the system is linear or has significant nonlinearities. With this method the PID parameters are tuned based on the performance of the controller during a step response with the goal of producing a response with minimal settling time and overshoot.

Polygon Matching in Overhead Images: Particle Tracks through Fields of Corners and Pixel Gradients

Siddharth Manay

UCRL-ABS-235769

We extract buildings from overhead imagery using flexible polygon models. We present our work-in-progress, a particle filter method for polygon tracking, where transition densities are based on the flexible polygon model and observations are gradient-corner and -side measurements. This method will handle missing corners and sides robustly.

Radiation Detection

Simon Labov, Session Chair

Center for Advanced Signal and Image Sciences

Signal Processing Challenges for Radiation Detection

Simon Labov
UCRL-ABS-236335

Technologies used for nuclear counterproliferation and counterterrorism are limited by combinations of basic physics, properties of key materials and costs. Signal processing techniques are under development to enhance performance of these systems including those currently in use, and more advanced systems under development. We present an overview of they key challenges that can be addressed by improved signal processing techniques. The talks that follow discuss some of these specific efforts in more detail.

Gamma-Ray Detector Resolution Study

Karl Einar Nelson
UCRL-PRES-227478

This presentation details an examination of the value of energy resolution in identifying sources using gamma ray spectroscopy. It is well established in the gamma ray spectroscopy community that to identify a source from a spectrum requires a minimum energy resolution from the detector. This work attempts to quantify this requirement in terms of the information content in the spectrum, the effects of noise on this information content, and the qualitative performance of a classification algorithm using this information.

A Bayesian Sequential Processor Approach to Spectroscopic Portal System Decisions

Kenneth Sale, James Candy, David Chambers,
Thomas Gosnell, Stanley Prussin, Dennis Slaughter
UCRL-PRES-234043

We present early results from our program to develop a faster, more reliable way to detect radioactive contraband in a portal type scenario. Toward this goal we have developed and implemented a model based, Bayesian, sequential data processor for the detection problem (classification and estimation will be developed in the future). In the sequential processor approach each datum (detector energy deposit and pulse arrival time) is used to update the estimated posterior probability distribution over the space of the model parameters. The nature of the sequential processor approach is that a result (e.g. red or green light for the detection problem) can be produced as soon as is statistically justified by the data rather than waiting for a fixed counting interval before analyzing any data. We discuss the Bayesian approach, our physics and signal processing models, potential decision functionals, and first results of our research.

A Comparison of Signal Processing and Classification Algorithms for Detecting the Presence of a Threatening Radiation Source

Barry Chen
UCRL-ABS-235808

The ability to detect the presence of threatening radiation sources hidden in cargo containers or vehicles is important to both nonproliferation and homeland security efforts.

One of the most basic approaches for detecting the presence of a threatening radiation source is to simply count and threshold on the number of Gamma rays detected; however, this approach often produces a high number of false alarms. Better approaches utilize the Gamma ray spectra which sorts the counts of the number of Gamma rays detected by their corresponding energy. In this work, we compare the performance of four different approaches to detecting the presence of injected radiation threats within the Gamma ray spectra measured from real vehicles. In particular, we compare two signal processing approaches, Matched Filter Analysis (MFA) and Orthogonal Subspace Projection (OSP), with two machine learning algorithms, Support Vector Machine (SVM) and Random Forest (RF). Receiver Operating Characteristic (ROC) curves are used to quantify and compare performance of each of the four approaches.

Contextually Aware Nuclear Evaluation System

Simon Labov[1], Michael Pivovaroff[1], Kelley Herndon Ford[1], Milovan Krnjajic[1], Doug Speck[1], Karl Nelson[1], Dov Cohen[2], John Estrada[2], Artur Dubrawski[3], Saswati Ray[3], John Ostlund[3], Josep Roure[3], Karen Chen[3]

[1]Lawrence Livermore National Laboratory, Livermore, CA 94550, [2]Sandia National Laboratory, Livermore, CA 94550, [3]Carnegie Mellon University, Pittsburgh, PA 15213

UCRL-ABS-235861

The ideal radiation detector system for homeland security would provide an unambiguous signal indicating the presence of a nuclear weapon, special nuclear materials (SNM) or a radiological weapon. In many cases, differentiation between signals from benign sources, such as naturally occurring radioactive material (NORM), medical isotopes and background fluctuations, and those from contraband agents can be achieved through spectroscopic classification and identification. The effectiveness of this differentiation depends largely on the spectroscopic resolution of the system. Currently, radiation portal monitors (RPMs) and hand held radioisotope identifiers (RIIDs) are used to detect and evaluate radioactive materials. When these systems detect radiation, a human expert is often required to intervene to resolve the situation. The expert typically considers the spectroscopic signal while incorporating contextual information (e.g., the size and weight of the container) and past experience in similar situations to make a determination to pass the shipment or initiate a detailed search. This requires a combination of a deep understanding of a specific problem and a hierarchical series of rules. We are developing a contextually aware nuclear evaluation system (CANES). CANES is based on machine learning (ML) algorithms that are trained through repeated exposure to sample incidents and are subsequently able to return an assessment (classification) of a new incident. We present here the overall system design including data inputs, feature vector extraction, and system operation. We will show how the system is optimized to ingest domain expertise directly from nuclear analysts to provide both decision support assistance and complete analysis.

This work was supported by the Domestic Nuclear Detection Office of the Department of Homeland Security.

Image Analysis of Radiographic Scans for Detection of Threats in Cargo Containers

Wilber A. McClay, Simon Labov

UCRL-ABS-236058

Radiographic imaging has become an important tool for screening cargo containers for potential nuclear or radiological threats. We are investigating methods to extract features from these images that, when combined with other measurements and information, could help indicate whether or not a threat is present. Analysis of single-energy radiographs is made particularly challenging by the large variety of cargo contents and the overall volume and mass of standard intermodel shipping containers. Our approach is to extract key features that characterize the contents in various ways, and then apply machine learning to these features along with feature vectors from other measurements and contextual information. These other features may include spatial profiles, gamma-ray spectra and neutron emissions from radioactive materials, weight, volume, location, condition, origin, shipper, destination, stated contents etc. We report here on analysis of 669 radiographic scans measured by a SAIC VACIS (Vehicle and Cargo Imaging System) at the Port of Oakland. We use Variational Bayesian Factor Analysis (VBFA) methods with Sobel Edge Detection to create features that separate images by overall category. We also extract features based on the overall statistical characteristics of the images. We then apply all of these techniques to all the images, as well as to a duplicate set of images that have a simple surrogate threat overlaid on each image. This allows us to characterize the variation in each feature due to the presence of a threat, and provide threat and non-threat training data for machine learning algorithms that could be used to analyze these features in combination with the features from other sources.

Time Reversal Based Ultra-wideband Radio Frequency Tags

Faranak Nekoogar, Farid Dowla

UCRL-ABS-235956

On-demand real-time identification and tracking of assets using radio-frequency identification (RFID) tags is a powerful technology for improving inventory control and tracking applications. Although there is vast commercial industry working on the RFID systems, the vulnerabilities of commercial products are only beginning to emerge. The main challenge faced by currently available commercial RFID tags is poor performance around cluttered channels including reflective environments (i.e. metallic objects). In this presentation we introduce a novel time reversal based technique for use in ultra-wideband (UWB) RF tags to improve their performance around metallic structures. The time reversal method generates a strong profile for the return signal from a tag by accurately estimating the channel impulse response.

Adaptive Optics

Lisa A. Poyneer, Session Chair

Center for Advanced Signal and Image Sciences

Performance of a MEMS-based AO-OCT System

Julia W. Evans, Robert J. Zawadzki, Steve Jones, Scot Oliver, John S. Werner
UCRL-ABS-235275

Adaptive optics (AO) and Optical coherence tomography (OCT) are powerful imaging modalities that, when combined, can provide high-resolution, 3-D images of the retina. The AO-OCT system at UC Davis has been under development for 2 years and has demonstrated the utility of this technology for microscopic, volumetric, in vivo retinal imaging. The current system uses an AOptix bimorph deformable mirror (DM) for low-order, high-stroke correction and a 140-actuator Boston Micromachines DM for high-order correction. We present our on-going characterization of AO system performance with particular emphasis on MEMS DM performance. Residual WFEs are broken down into constituent errors in an error budget including sources like calibration and bandwidth. Careful characterization of the AO system will lead to improved performance and inform the design of future systems.

Compact Adaptive Optics Scanning Laser Ophthalmoscope

Diana C. Chen, Steven Jones, Dennis Silva, Scot Olivier
UCRL-ABS-353565

Ophthalmology is unique among medical specialties in that most of the effects of disease can be directly viewed by looking into the eye. For years, ophthalmologists have used observations of the retina to diagnose and monitor a wide variety of progressive, blinding diseases. Now, through a joint, cooperative effort, a MEMS-based Adaptive Optics Scanning Laser Ophthalmoscope (MAOSLO) has been developed to measure and automatically correct aberrations in the eye in real-time; provide non-invasive, in vivo images of the retina at the cellular level; enable optical sectioning of different cellular layers in the retina; and produce a permanent, digitized record of clinical observations to facilitate monitoring of disease progression and the effects of therapeutic treatments. This is the first instrument that will enable clinicians to image and measure microscopic structures of the living eye, such as individual photoreceptors and ganglion cells. Clinical trials have demonstrated that the instrument's unprecedented resolution and 3-D sectioning capability represent a revolutionary breakthrough in the visualization of the retina, enabling the early diagnosis of retinal diseases and non-invasive monitoring of medical treatment.

Kalman Filtering for Predictive Wavefront Control in Adaptive Optics

Lisa A. Poyneer

UCRL-ABS-235240

We present a computationally efficient and adaptive method for predictive wavefront control in Adaptive Optics. This method is based on Fourier Transform reconstruction, in which the phase aberration is reconstructed from the wavefront sensor slopes with a Fourier-domain filtering technique. The predictive control is then accomplished by using an independent temporal filter for each Fourier mode which converts the residual phase into the deformable mirror commands. This predictive controller is the steady-state Kalman filter and is based on a state-space model for the evolution of the frozen flow atmosphere and AO control system. Model parameters are estimated from closed-loop telemetry.

Iterative Shack-Hartmann Wave-Front Sensing for Open-Loop Metrology Applications

Kevin Baker

UCRL-ABS-235531

Numerous techniques exist to reconstruct the wave-front in Shack-Hartmann and shearing interferometer wave-front sensors. Several of these techniques involve solving the least squares phase reconstruction via Fourier Transforms or Multigrid methods. These techniques are sensitive to boundary conditions and nonlinearities due to large aberrations. In this article we introduce an iterative computational loop in the reconstruction process which is designed to improve the reconstruction variances introduced by these parameters. This technique allows for accurate reconstruction of large phases which can arise in applications such as open-loop compensation of atmospheric turbulence, aberrometers and metrology. In this presentation, it is demonstrated that large aberrations can be accurately reconstructed utilizing this iterative method. Several examples applications are examined including an aberrometer application and an x-ray backlighting example.

National Ignition Facility (NIF)

Ric Beeler, Session Chair

Center for Advanced Signal and Image Sciences

Final Optics Damage Inspection for the National Ignition Facility

Alan Conder, Stephen Azevedo, Jim Chang, Wade Williams, Mary Spaeth Judith Liebman, Pam Whitman, Mike Nostrand, Laura Kegelmeyer, Steven Glenn

UCRL-ABS-232479

Large aperture optics in the National Ignition Facility (NIF) at the Lawrence Livermore National Laboratory (LLNL) will be routinely inspected in-situ for laser-induced damage. After high fluence shots (exceeding 4J/cm^2 at 350 nm), the final optics, located at and near the 3ω conversion point on the target chamber, will be inspected. This inspection is the "corner stone" of the NIF optic recycle strategy. The FODI (Final Optics Damage Inspection) system is being developed for this purpose, with requirements to detect damage initiation and to track and size the growth of the damage to the point at which the optic is removed and the damage mitigated. We will describe the FODI (Final Optics Damage Inspection) system and discuss the challenges to make optics inspection a routine part of NIF operations.

Automated Inspection for NIF Final Optics

Judy Liebman, Laura Kegelmeyer, Amber Marsh, Dan Potter, David Lau

UCRL-ABS-235651

The NIF project will soon begin to commission the final section of beampath between the main laser and the target chamber. The final optics are the last set of optics that the laser passes through before hitting the target. These optics are operated at or near their threshold of damage and for this reason will require periodic inspection during operations. As part of the NIF final optics damage inspection system (FODI) automated inspection analysis software will be used to detect, size, and track laser damage, and also to establish the precise location of damage in the coordinate frame of the optic. Unambiguous location information is important for subsequent characterization and treatment of damage in offline facilities, and typically requires registration of online and offline data to better than 1mm accuracy. In this talk I will present analysis upgrades and algorithms that make this possible and examples of automated inspection results from recent full aperture tests on NIF.

Avatar Machine Learning for NIF Optics Inspection Analysis

Laura Mascio Kegelmeyer, Judy Liebman, Amber Marsh, Simon Chou, and Philip Kegelmeyer

UCRL-ABS-235593

For several years, the automated NIF Optics Inspection system has routinely been acquiring and analyzing images from thousands of optics both on and off the NIF beamline. Optics are inspected to assure quality before being installed and are continually monitored once on the beamline.

By design, the analysis has been conservative in reporting candidate flaws, eventually resulting in too many false positives and thus time-consuming follow-up by operators. Now, however, we have successfully applied the Avatar machine learning codes (see presentation by Philip Kegelmeyer), and achieved >99% accuracy in removing false positives. Here we present methods for data preparation and training the algorithms as well as operational performance on the NIF.

Why and How to Exploit OOB Validation for Ensemble Size

Philip Kegelmeyer, Sandia National Laboratory

SANDIA 2007-6608A

Ensembles are a machine learning meta-method. When applied properly to machine learning algorithms, they increase accuracy, reduce design stress, and clarify algorithm and feature design. They are being used to those ends in the LLNL NIF Optics Inspection program.

The key to effective use of ensembles is the concept of "out of bag" (OOB) accuracy. This talk will explain OOB accuracy, describe an algorithm for its use in selecting ensemble size, and compare its nature and use with that of cross-validation accuracy.

Automatic Alignment System for the National Ignition Facility

K. Wilhelmsen, A. Awwal, W. Ferguson, B. Horowitz, V. Miller Kamm, C. Reynolds
UCRL-Conf-235329

The automatic alignment system for the National Ignition Facility (NIF) is a large-scale parallel system that directs all 192 laser beams along the 300-m optical path to a 50-micron focus at target chamber in less than 30 minutes. The system commands 9,000 stepping motors to adjust mirrors and other optics. Twenty-two control loops per beamline request image processing services running on a LINUX cluster to analyze high-resolution images of the beam and references. Process-leveling assures the computational load is evenly spread on the cluster. Algorithms also estimate measurement accuracy and reject off-normal images. One challenge to achieving rapid alignment of beams in parallel is the efficient coordination of shared laser devices, such as sensors that are configurable to monitor multiple beams. Contention for shared resources is managed by the Component Mediation System, which precludes deadlocks and optimizes device motions using a hierarchical component structure. A reservation service provided by the software framework prevents interference from competing instances of automated controls or from the actions of system operators. The design, architecture and performance of the system will be discussed.

What Can We Learn from the Correlation Shape?

Abdul Awwal
UCRL-ABS-235839

Correlation is a popular method of finding an object of interest in a scene or detecting signal in the presence of noise. The common approach for correlation detection is to threshold a normalized peak. With an undistorted object this may work. However, when the object suffers from various optical distortions, this technique alone is not enough to provide a good indication of a match. Interestingly, the shape of the correlation gives us sufficient clues whether a match is valid or invalid. We show this with examples from automatic alignment laser beam images used in the National Ignition Facility. We introduce terms like double peak and broad peak to identify various shapes of the correlation function. Using these we are able to avoid false matches and find the best match under very challenging optical distortions.

Application of Linear Systems Signal Processing Techniques for Remote Calibration of LVDT Systems

David Bloom

UCRL-ABS-235541

This paper investigates the ability to calibrate an LVDT (Linear Variable Displacement Transformer) system in one configuration, and then use Linear Systems Signal Processing techniques to adjust this calibration for a different LVDT system configuration. In many cases, output of LVDT systems require calibration in order to attain system level precision requirements. Unfortunately, the ability to calibrate LVDTs in situ in the final system configuration is often difficult and sometimes impossible due to logistic issues. The result of this investigation is a method to replace the need for in situ calibrations of LVDT Systems.

NIF VRT Pinhole Alignment Algorithm

Joshua Gordon, Computing Applications Research, LLNL, John Heebner, Engineering Technologies LLNL, Joyce Ho, Laser and Systems Engineering, LLNL

UCRL-ABS-235450

The NIF Pre-Amplifier Modules (PAMs) incorporate 2 Vacuum Relay Telescopes (VRTs) for imaging between relay planes, parasitic suppression, and spatial filtering. Each telescope contains an array of 4 pinholes that are optimally sized small enough to filter high spatial frequency scattered light yet large enough to prevent spatial filtering of the wings of the spread farfield focal spot when smoothing by spectral dispersion (SSD) is applied. Mechanical drift can cause the precise overlay of the 8 pinholes to degrade over time and adjustments will need to be made in the laser bay by qualified technicians. In order to minimize downtime in NIF operation, a real-time means of assessing pinhole overlay precision is required. The purpose of the commissioning algorithm is to quantify the magnitude and direction of the pinhole offsets by analyzing overfilled illumination patterns on a farfield camera positioned at the conjugate plane of the pinholes. The pinhole reconstruction algorithm is complicated by diffraction patterns, noise, and saturation. This presentation discusses the continuing effort to enhance the precision and speed of the alignment algorithm.

Terahertz Imaging

Farid Dowla, Session Chair

Center for Advanced Signal and Image Sciences

Standoff Detection of High-Explosives Using THz Imaging Spectroscopy

Farid U. Dowla, Michael Burke, Gregory Klunder, and Robert J. Deri

UCRL-JRNL-235289

Unique spectral characteristics of energetic materials from a back-scattered terahertz (THz) wavefield suggest that spectroscopic imaging with back-scattered THz waves has the potential to be a key technology in the detection of high explosives (HE) at standoff distances (>10 meters). The ability of THz waveforms to penetrate plastics and clothing makes them particularly useful. However, a field-deployable THz sensor that can overcome severe atmospheric absorptions and reliably detect HE at standoff distances remains a design challenge. To address system and waveform design issues, we employ signal processing modeling and simulation to demonstrate that adaptive deconvolution and wideband equalization techniques can play a significant role in the design of a long-standoff detection system. Numerically derived receiver operating characteristic curves, reported here for the first time, indicate that even for standoff distances as high as 50 meters, a well-designed THz system can detect targets with an accuracy of at least 95% probability of detection and a probability of false alarm of <1%. Detailed descriptions of the signal modeling, estimation, and detection algorithms are also discussed.

Terahertz Spectroscopic Imaging for First Responders

Michael W. Burke

UCRL-ABS-235697

The First Responder task is a difficult one, requiring the initiation delay and/or rendersafe of a potentially explosive package with minimal or no knowledge of the internal structures of the device. Also, the device may contain sensors designed to detect intrusive examination, setting off the device. There are several exciting new technologies for stabilization/rendersafe of a device, but it is critically important that such techniques be used without themselves causing initiation. The diagnostics portion of the problem is therefore an important adjunct. The First Responder must have the maximum knowledge of the interior of a suspicious package possible, to locate the fireset and any potential intrusion detectors, and to find where there are explosive charges (and of what type), in order to effectively and safely use stabilization and rendersafe technology.

Terahertz (THz) radiation can penetrate most covering/enclosing materials (except metal) while having the spatial resolution needed to image wiring and other internal structures. Importantly, this technology has the additional capability to yield spectral information about interior components, including determining if bulk HE is present (and what its chemical makeup is). In addition, it is very difficult to develop or purchase intrusion detectors for THz radiation. This technology is inherently safe for the public and for equipment operators, and does not modify the package contents (allowing forensic postmortems). The primary shortcoming of THz radiation (apart from immature COTS support) is its inability to propagate through any significant distance of atmospheric water. This limits its standoff range to less than 1 meter but this distance is acceptable for many First Responder scenarios.

Using modifications to existing LLNL THz capability, we have tried to establish the feasibility of a terahertz radiation scanner to examine the interior structure of a package, including the probing for the presence of HE. We will also examine its capability to image the interior of walls, tracing the wiring to junction boxes, sensors, etc. Using covering material and spectral data gathered from previous THz studies, we undertaken the development of a short standoff spectral imaging model, and will run simulations to understand the issues involved. We will then perform experiments to empirically validate this model and to establish the sensitivity of the model parameters.

This work when completed, will form the basis for using THz scanning for container diagnostics for stabilization teams, including predicting performance measures (ROCs) for typical First Responder scenarios.

Nondestructive Evaluation

Harry E. Martz, Jr., Session Chair

Center for Advanced Signal and Image Sciences

Nondestructive Evaluation Technologies to Defend the Homeland

Harry E. Martz, Jr.
UCRL-ABS-207194

Over the past 20 years, the Transportation Security Administration (TSA)–formerly the Federal Aviation Administration (FAA)–invested extensively in the development of systems designed to protect the traveling public from attacks on the commercial aviation system using explosives. These efforts have resulted in the deployment of two kinds of technologies for screening of luggage: explosive detection systems (EDSs), which are certified by TSA to detect bulk quantities of explosives in checked luggage, and explosive trace detectors (ETDs), which are designed to detect vapor or particles of explosives that would be associated with passenger items or luggage as a result of bomb fabrication or transportation.

Events of September 11, 2001–terrorist destruction of the World Trade Center utilizing commercial aviation as a vehicle–have changed our country's view on the urgency and scope of the threats of terrorist acts against the United States. The scope-of-threats extend beyond explosives and weapons to include radiological dispersal devices, and chemical, biological and nuclear weapons of mass destruction. Many different government entities, universities, and corporations are researching and developing technologies and methods for detection, identification, mitigation, and control of such threats. The presentation will summarize some of these efforts and focus somewhat on nondestructive evaluation technologies developed for detection and identification of explosive threats to aviation security, and how they may or may not apply to the expanding threats and other modes of transportation.

Ultrasonic Determination of HE Density

R. Huber, S. Benson , P. Souza
UCRL-ABS-235679

The use of ultrasound as a means of determining the density in HE was investigated. Contact ultrasonic tests were performed on HE pellets pressed to three different densities. Clear differences in the transit time of the ultrasound through the samples were measured. Thus, ultrasonic velocity can be used as a means of determining the density for HE. Supporting data will be presented, and an ongoing project to develop an automated, air-coupled ultrasound system for non-contact density determination will be discussed.

Xradia MicroXCT: A 3D X-Ray Computed Tomography System

John Sain, Bill Brown, Diane Chinn, Harry Martz Jr., Kenn Morales, Dan Schneberk, & Earl Updike
UCRL-ABS-235518

The Non-Destructive Evaluation (NDE) group within the Engineering Technologies Division (ETD) provides multi-dimensional, non-invasive, x-ray/ultrasound imaging of a variety of objects manufactured by several LLNS programs.

The Xradia MicroXCT, a 3D x-ray computed tomography (CT) system built by Xradia (Concord, CA), is a key tool within the suite of imaging systems maintained/operated by NDE. The MicroXCT system provides 2D/3D, high-resolution, high-contrast imaging of objects having overall dimensions on the order of millimeters and feature dimensions on the order of microns. The NDE group maintains and operates two – one 2D and one 3D – MicroXCT systems.

We will present detailed information on system capabilities, system characterization (e.g. MTF, SNR), and system limitations and potential problems. We will also show a variety of imaging results from recent efforts including, in particular, imaging studies performed for the High Energy Density Physics (HEDP) Target Fabrication Group.

Model-Based Algorithms for Detecting Cable Damage from Time-Domain Reflectometry Measurements

Grace A. Clark, Katherine A. Wade, Christopher Robbins

UCRL-ABS-235724

Critical cables can undergo various types of damage (e.g. short circuits, open circuits, punctures, compression) that manifest as changes in the dielectric properties of the cables. Only one end of the cable is accessible, and no exemplars of actual damage are available.

This work addresses the detection of dielectric anomalies in transient time domain reflectometry (TDR) measurements on the cables. Machine learning classification algorithms are effectively eliminated from consideration, because only a small number of cables is available for testing; so a sufficient sample size is not attainable. Nonetheless, a key requirement is to achieve very high probability of detection and very low probability of false alarm. Empirical studies to date show that the TDR measurements can be made reasonably repeatable from test to test on the same cable, and from cable to cable. This enables the use of a two-step model-based approach to cable damage detection.

Step 1, Cable Modeling:

Given input-output TDR signals $s(t)$ and $x_u(t)$ for a cable known to be free of damage, system identification algorithms are used to compute a dynamic prediction-error cable model that has output $\hat{x}_u(t)$. The model is declared valid when the innovations $e_u(t) = x_u(t) - \hat{x}_u(t)$ satisfy a statistical zero-mean whiteness test. This validated model output is then used as a known reference to which other cables can be compared.

Step 2, Cable Testing:

The TDR output signal $x_D(t)$ from a cable under test is compared with the model output $\hat{x}_u(t)$ by computing the innovations $e_D(t) = x_D(t) - \hat{x}_u(t)$. The innovations are tested using a short-term whiteness test statistic, which employs a statistical confidence interval. If the cable passes the test, this implies that the model is valid and the cable is declared undamaged. If the cable fails the test, this indicates a model mismatch, which means that the cable's dielectric properties have changed; and this implies that the cable is damaged. The test threshold is adjusted to maximize probability of detection and minimize probability of false alarm according to an empirically determined receiver operating characteristic (ROC) curve. An associated confidence interval on the probability of correct classification is also provided.

The effectiveness of the algorithm is demonstrated using measured TDR signals for undamaged and damaged cables.

Development of an Acoustic Backpropagation Method to Detect and Localize Changes In An Instrumented Structure

D. H. Chambers, K. Fisher, J. V. Candy, B. Guidry, E. Breitfeller

UCRL-ABS-235706

A backpropagation method is presented that allows for the detection and localization of structural changes in an instrumented part. Experimental measurements are made on a structure before and after damage, from these measurements, a series of residuals at discrete frequencies are calculated at the sensor locations using spectral processing techniques on the measured displacements fields. The residuals are then 'time-reversed' and used as sources in a finite element model of the structure. A superposition of the discrete residual responses yields a localization field where the vibrational energy is focused to the site of the damage and thus located. Numerical and experimental results will be given.

NOTES

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Signal and Imaging Sciences Conference Survey
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Thank you for attending the Signal and Imaging Sciences Conference. We would appreciate your input for future conferences.

1. Length of the presentation at the CASIS Conference:

   _____ Too long
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   _____ Just right

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   _____ Very good
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Please return this form at the end of the Conference or send to Vickie Abreu at L-130 or email at: abreu2@llnl.gov.

Thank you,
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