Electrical Engineering Department

CAPT Robert J. Voigt, USN
Chair

Research and scholarly activity are fundamental to the vitality and viability of any discipline. This is particularly applicable to electrical engineering, which is broadly based and rapidly expanding. Research helps both faculty and midshipmen keep abreast of advancing technology and ultimately improve the effectiveness of the academic environment by encouraging a modern and relevant curriculum.

Funding for our research comes from the Office of Naval Research (ONR), the Naval Research Laboratory (NRL), the Naval Surface Warfare Center (NSWC), the Johns Hopkins University Applied Physics Laboratory (JHU/APL), the National Security Agency (NSA), The Advanced Technology Institute, the Army Research Laboratory (ARL) and from within the Naval Academy.

Research topics supported during the past year included an initiative in control and reconfiguration of shipboard electric power systems, distributed control of shipboard systems, stability of shipboard electric power systems, various aspects of digital signal processing (including image and video processing, adaptive DSP, and reconstruction of periodic signals), development of micro-electro-mechanical microwave switches and thermal control devices, packaging of microwave and optical components, design of wireless sensor system/power nodes, near earth RF propagation, high power vacuum electronics, electronic reliability, operation and control of buck converters, study of radio frequency identification principles and applications, development of optical local area networking protocols, biometric signal processing including partial iris recognition and design and implementation of advanced mathematical algorithms on field programmable gate array hardware. Faculty and midshipman research efforts contribute directly to the fleet's operational capabilities, and provide relevant topics which benefit the professional as well as the academic development of our midshipmen.

Sponsored Research

Office of Naval Research (ONR) National Naval Responsibility Electric Ship Integration Initiative

Researchers: Associate Professor John G. Ciezki
and Associate Professor Edwin L. Zivi, Jr. (Weapons and Systems Engineering Department)
Sponsor: Office of Naval Research (ONR) and Advanced Technology Institute (ATI)

The researchers are involved in a multi-institutional research project with both pedagogical and fundamental research deliverables. At the U.S. Naval Academy, year three focused on modeling and simulation efforts. Specifically, the investigator teamed with researchers at Purdue University and Anteon Corporation to develop a fluid system model for a representative next-generation surface combatant power system. The fluid layer was integrated with an AC and DC electrical system model and a simple thermal system model. The goal of the research is to enable the optimal design of a system of systems (optimal from the standpoint of survivability). The investigator (JGC) devised a nonlinear resistive-source static model of a three-zone distributed chilled-water system, and then devised a Newton-raphson based solution. The solution was coded first in MATLAB®, then converted to ACSL. The ACSL solution was finally macroized and delivered to Purdue University in the form of a library of models. The library was then integrated into a system-wide simulation and results were generated and presented to the sponsor.

New Iris Recognition Algorithms

Researcher: Assistant Professor Robert W. Ives
Sponsor: Intelligence Technical Innovation Center (ITIC)

This research project has a single major objective: to develop new iris recognition algorithms. Within this major goal, there are several related objectives, including: (1) Creating an iris database. (2) Comparing some leading iris recognition algorithms using a standard set of raw iris images. (3) Developing new computationally efficient matching algorithms and compare their performance to leading algorithms. A significant portion of this research funding is to support a postdoctoral research fellow.

Biometric Signal Processing at the United States Naval Academy

Researchers: Assistant Professor Robert W. Ives, Professor Delores M. Etter,
Assistant Research Professor Lauren R. Kennell, Commander Thaddeus B. Welch, III, USN,
and Lieutenant Robert C. Schultz, USN
Sponsor: National Security Agency (NSA)

This research project has two objectives: (1) to develop a multi-modal biometric collection station that can capture iris, face, fingerprint and voice; and (2) to provide equipment support for midshipman research projects in biometrics. Using a multi-modal biometric approach, the accuracy rate of a biometric system should be noticeably improved. Once these multi-modal biometric samples are captured, the challenge of data (or sensor) fusion must be addressed: how to combine the information from several sensors in order to perform recognition. The collection of this data is a first step in the process of developing an algorithm for sensor fusion. Midshipman research projects may include Trident Scholar projects, senior design projects, and/or projects that form a part of the EE488c Biometric Signal Processing course. The Naval Academy Biometric Signal Processing Laboratory contains state-of-the-art equipment to support these goals.

Steady-State Analysis of Stimulated Brillouin Scattering in Optical Fiber

Researcher: Associate Professor R. Brian Jenkins
Sponsor: Dr. Ray Sova, The Johns Hopkins University Applied Physics Laboratory (JHU/APL)

This project focuses on the analysis and numerical modeling of Stimulated Brillouin Scattering (SBS) in optical fiber in the steady-state regime. The research is in support of ongoing experiments at The Johns Hopkins University Applied Physics Laboratory attempting to optically extract a high-speed digital clock from a stream of data (at arbitrary data rates of 10-40Gb/s). SBS is the fiber nonlinearity with the lowest threshold power in many systems. SBS is a nonlinear interaction between three waves, a forward-propagating optical pump, a backward-propagating optical Stokes wave (downshifted 11GHz from the pump), and an acoustic wave (at 11GHz) that leads to material density fluctuations (in the index of refraction). Optical pump energy is scattered off the grating in the direction of the Stokes wave. Hence SBS often causes strong fluctuations in energy levels, leading to signal degradation in many fiber optic systems. SBS can also be used productively for amplifiers, sensors, and clock recovery. The goal of this project has been to understand the steady-state characteristics of the SBS process, with emphasis on the spontaneous growth of noise due to SBS. Analytical and numerical models were developed that accurately predict the steady-state behavior of SBS observed in the laboratory.

Wavelength Conversion and Network Technologies

Researchers: Associate Professor R. Brian Jenkins
Dr. Ray Sova, The Johns Hopkins University Applied Physics Laboratory (JHU/APL)
Sponsor: U.S. Naval Academy Sabbatical Program

The purpose of this sabbatical was to pursue research on wavelength conversion techniques and optical network technologies using optical fiber. These topics are increasingly important to both the United States Navy and the United States Naval Academy (USNA). Recent Trident Scholars at the Naval Academy have investigated such issues, related concepts are regularly discussed in EE472, the senior elective course in fiber optics at USNA, and the Department of Defense (DoD) and Department of Navy regularly support research in these areas.

This effort enhanced collaborative research in fiber optics between The Johns Hopkins University Applied Physics Laboratory (JHU/APL) and the Naval Academy. The current research efforts at JHU/APL have focused on the use of nonlinear processes (specifically, stimulated Brillouin scattering) in high performance fiber optic receivers. Wavelength conversion technologies can be used to improve performance of such receivers, and will be fundamental components in future all-optical networks.

During the sabbatical, efforts included characterization of Sagnac-interferometer based wavelength converters, including the modeling and simulation, as well as implementation of such devices. Specific tasks included creation and implementation of the numerical models that describe the behavior of wavelength converters in the receiver, and possibly in more general applications, such as optical networks. Further research characterized mixed signal propagation in optical mesh networks, and in addition, emphasized techniques to insure re-configurability in mesh networks that use wavelength conversion for routing.

Advanced Packaging Applications

Researcher: Associate Professor Deborah M. Mechtel
Sponsor: The Johns Hopkins University/Applied Physics Laboratory (JHU/APL)

Wide bandwidth applications have driven the demand for optical waveguides and other components for the processing and transmission of information. Polymers are attractive materials for optical waveguides at both the chip and substrate levels because of their desirable electrical and optical properties as well as their ease of processing. A technique to simultaneously use polyimide as both a dielectric layer and an optical waveguide in the same multichip substrate structure is under development. This technique, using poled polymers, will permit electrical and optical interlayers to be formed simultaneously, thus allowing buried optical waveguide and electrical signal lines on the same MCM-D.

A technique that employs a noninvasive, laser-based instrument is used to probe MCM structures fabricated with poled polyimide interlayer dielectrics and thin film metallizations on silicon carriers. The electro-optic interaction between the poled dielectric and the laser beam allows the strength of the internal fields within the MCM to be determined as a function of position. Electric field measurements and mappings can be useful in diagnosing module performance, locating sites of circuit shorts and opens, and determining the efficacy of field containment structures. The detection of electric fields in polyimide with buried circuit elements in multiple layers characteristic of MCM-D structures is being studied. Test systems of two dielectric layers with one metal interlayer are being studied.

The details of the poling and processing operations along with the mechanical, thermal, electrical, optical and electro-optic properties for both lightguide and dielectric layer applications are being examined.

Evaluation of Water-cooled Heat Sinks

Researcher: Assistant Professor Thomas E. Salem
Sponsor: U.S. Army Research Laboratory (ARL)

This project involved designing and developing a test procedure for evaluating a novel IGBT half-bridge module that contained in integral liquid cooled microchannel heat sink. Thermal characterization of the packaged device was accomplished through experimental testing and evaluation.

Thermocouple Coating Study

Researcher: Assistant Professor Thomas E. Salem
Sponsor: U.S. Army Research Laboratory (ARL)

This project explored the use of thermally conductive, electrically isolating epoxies on thermocouples for direct temperature measurement of active power electronic components.

Analysis of an Airborne Missile-Defense System

Researcher: Professor Antal A. Sarkady
Sponsor: Naval Research Laboratory (NRL)

The Naval Research Laboratory (Code 5663.00) has been given the task to develop an airborne missile defense system suitable for low flying airplanes and helicopters. In the past five years, they have developed an airborne two-pod optical hardware system consisting of an infrared (IR) sensor (located in pod number one) that detects the incoming missile and turns on a laser (located in pod number two) that defeats the guiding system of the incoming missile and flies the missile into the ground. This system has been tested and currently is going into full production for the F18 fighter planes. More recently, NRL is attempting to combine these two pods into a single-pod system that is suitable for helicopter defense. Because the helicopters fly at lower altitudes, the response time to detect and defeat an incoming missile is a great deal shorter than it is for the F18 defense scenario. Many challenging technical problems have to be overcome before the helicopter defense system matures to be a reliable airborne defense system. These include substantial weight reduction and substantial improvement in pointing accuracy and response time.

This project is a team effort between NRL, industry and academic consultants to bring an ambitious project like this to a successful conclusion. The USNA role in this project is to function as an advisor and troubleshooter that focuses on "show-stopping" problems and provides possible solutions to these problems. The solutions often require computer simulations, laboratory modeling and extensive study of components that meet the exacting specifications required by the airborne defense system.

Design of a Silicon Carbide (SiC) RF Limiter

Researchers: Assistant Professor James D. Zuber,
Dr. Kenneth O'Haver and Mr. Bruce A. Kopp,
Radar Systems Development, The Johns Hopkins University Applied Physics Lab (JHU/APL)
Sponsors: The Johns Hopkins University, Applied Physics Lab and NAVSEA PEO/IWS

The Naval Academy provides technical support for high power RF and microwave subsystem investigations at JHU/APL in support of advanced phased-array (PA) radar systems development tasks sponsored by the PEO IWS 2.0; specifically, to support development of advanced semiconductors related to the development of future PA radar and communications systems. Development areas include the analysis and assessment of technical issues for wide bandgap (WBG) semiconductors, including silicon carbide (SiC), gallium nitride (GaN) devices and novel gallium arsenide (GaAs) devices. JHU/APL is providing technical expertise and leadership for system engineering, design, development, and system integration efforts leading to the development and fielding of Cobra Judy Replacement and next-generation PA radar systems for Theater Air and Ballistic Missile Defense. This work will continue for the remainder of FY06.

Recent effort has focused on the design of a solid-state RF diode limiter that can protect the sensitive receiver of a phased array radar from any inadvertent high power RF signals that may be passed from the duplexer. Silicon and GaAs do not handle the power levels and temperatures that may arise from very high RF power levels, so there is some interest in the feasibility of developing a silicon carbide diode to perform the intended function.

Midshipmen Design Projects

Comms Challenge Using Alteras

Researchers: Midshipman 1/C Daniel B. Bartle, USN and Midshipman 1/C Daniel E. Moran, USN
Advisers: Professor Richard L. Martin and Lieutenant Mark O. Thomas, USN

SolarSplash: Power and Monitoring System

Researcher: Midshipman 1/C Kyle M. Beilke, USN
Advisers: Assistant Professor Samara L. Firebaugh, Lieutenant Jonathan J. Kim, USN
and Major Charles A. Hulme, USMC

Human Tracking via Soft Biometrics
Researchers: Midshipman 1/C Adam J. Bergeron, USN and Midshipman 1/C Robert Szeligowski, USN
Advisers: Assistant Professor Robert W. Ives and Commander Thaddeus B. Welch, III, USN

Nth Order Fir-Based Equalizer
Researcher: Midshipman 1/C Allison M. Cady, USN
Advisers: Commander Thaddeus B. Welch, III, USN and Professor Richard L. Martin

SolarSplash: Motor and Load Matching
Researcher: Midshipman 1/C Matthew J. Frederick, USN
Advisers: Assistant Professor Samara L. Firebaugh, Lieutenant Jonathan J. Kim, USN and Major Charles A. Hulme, USMC

Model Train Board Simulation
Researchers: Midshipman 1/C Thomas H. Hawkins, USN and Midshipman 1/C Daniel P. Zastrow, USN
Advisers: Assistant Professor Thomas E. Salem and Assistant Professor Ryan N. Rakvic

A Transmission Line Matrix Demonstrator
Researcher: Midshipman 1/C Andrew P. Hornfeck, USN
Advisers: Captain Joseph C. McGowan, USN and Associate Professor Louiza Sellami

Soft Drink Rejuvenator
Researchers: Midshipman 1/C Mark S. Justiss, USN
Advisers: Commander Charles B. Cameron, USN and Captain Robert J. Voigt, USN

DSP-Based Transmitter / Receiver with FSK
Researcher: Midshipman 1/C Micah A. Kolcun, USN
Advisers: Commander Thaddeus B. Welch, III, USN and Professor Antal A. Sarkady

Multi-stage Coil Gun
Researcher: Midshipman 1/C Joseph M. Mathis, USN
Advisers: Associate Professor John G. Ciezki and Major Robb P. Mansfield, USMC

Blue Cell IED Project
Researchers: Midshipman 1/C Aric L. McElheny, USN and Midshipman 1/C Andrew E. Tingley, USN
Advisers: Commander Thaddeus B. Welch, III, USN and Assistant Professor James D. Zuber

Comms Challenge Using DTMF
Researchers: Midshipman 1/C James C. Ripley, USN and Midshipman 1/C Edward C. Tremblay, USN
Advisers: Professor Richard L. Martin and Major David A. Moore, USMC

Magnetohydrodynamic (MHD) Propulsion
Researcher: Midshipman 1/C Bradley J. Roberts, USN
Advisers: Associate Professor John G. Ciezki and Commander Andrew C. McCue, USN

Rube Goldberg Tea-bag Dipper
Researchers: Midshipman 1/C Joshua G. Sanborn, USN and Midshipman 1/C Duane B. Willoughby, USN
Advisers: Associate Professor John G. Ciezki and Lieutenant Colonel Dean A. Ebert, USMC

Child Car Seat Alarm

Researchers: Midshipman 1/C Kristfer A. Tester, USN, and Midshipman 1/C Raphael J. Thalakottur, USN
Advisers: Assistant Professor Samara L. Firebaugh and Assistant Professor Thomas E. Salem

Automated Smart Sprinkler System

Researcher: Midshipman 1/C Jeffrey W. Whitsett, USN
Advisers: Captain Robert J. Voigt, USN and Captain Joseph C. McGowan, USN

DSP-Based Guitar Effects Pedal

Researcher: Midshipman 1/C Justin R. Wolfe, USN
Advisers: Commander Thaddeus B. Welch, III, USN and Captain Joseph C. McGowan, USN

Child-Safe Room

Researcher: Midshipman 1/C Jennifer M. Yedoni, USN
Advisers: Lieutenant Robert C. Schultz, USN, Assistant Professor Robert W. Ives,
and Lieutenant Bryan T. Burke, USN

FIRST Robotics

Researchers: Midshipman 1/C Katherine L. Gerhard, USN, Midshipman 1/C Brian J. Robinson, USN
and Midshipman 1/C Anthony L. Williams, USN
Advisers: Major Mark E. Tingle, USMC, Assistant Professor Ellen C. Wooten,
and Lieutenant Eric A. Schuchard, USN

SAE Car

Researcher: Midshipman 1/C Christopher M. McConnell, USN
and Midshipman 1/C Lloyd J. Vander Schaaf, USN
Advisers: Lieutenant Colonel Dean A. Ebert, USMC and Professor Richard L. Martin

Trident Scholar Projects

Using Non-Orthogonal Iris Images for Iris Recognition (Trident Report # 342)

Researcher: Midshipman 1/C Ruth M. Gaunt, USN
Advisers: Assistant Professor Robert W. Ives and Professor Delores M. Etter
Sponsor: Office of Naval Research (ONR)

This research investigated the use of non-orthogonal iris patterns for iris recognition. Identifying individuals from partial iris images taken from off-axis angles will aide in the solution to the larger problem of covert iris recognition. Midshipman 1/C Brad Bonney's 2004-2005 Trident Project research involved developing an algorithm to extract partial iris patterns from an image of an eye taken from an off-axis angle with a near-infrared camera. This research continued his project. It involved determining the maximum angle that an iris can be off-axis from the camera lens and still be used to positively identify an individual. A database of iris images that are taken from a variety of off-axis angles was created using a near-infrared camera. An algorithm was then developed to use these images to positively identify new iris images that are presented at off-axis angles to the camera lens.

Iris recognition is a highly effective biometric with a cooperative user trying to gain access to secure systems and information. However, it is not currently used in a covert identification system. The research involved in this project will ultimately aid in the solution to this problem by developing a way to take the extracted iris patterns in an off-axis iris image and use them to positively identify individuals.

Using All-Optical Wavelength Conversion for Routing In Optical Local Area Networks (Trident Report # 344)

Researcher: Midshipman 1/C Clifford N. Jessop, USN
Advisers: Associate Professor R. Brian Jenkins and Captain Robert J. Voigt, USN
Sponsor: Office of Naval Research (ONR)

All-optical wavelength conversion is a process that is used to reduce the number of optical-electrical-optical (O-E-O) conversions in an optical network. Limiting O-E-O conversions reduces latency for signals propagating through the network. The focus of this project is to implement all-optical wavelength conversion in the physical layer of an optical local area network (LAN) to observe its effect on system performance. Several types of wavelength converters have been considered for such a network, specifically those using cross-gain modulation (XGM), cross-phase modulation (XPM), four wave mixing (FWM), and difference frequency generation (DFG). Particular attention is paid to the effect on latency, bit error rate (BER), and analog spur free dynamic range (SFDR). Analyses have been done using both computer simulation and a hardware test bed, emphasizing XGM and XPM converters. Ultimately, all-optical wavelength converters are desired for use in mixed signal networks, where both analog and digital data propagate through the network. As a baseline, measurements taken on a particular wavelength division multiplexed LAN indicate the capacity to handle 10 Gbps digital signals and analog operation with a spur free dynamic range (SFDR) of 113 dB-$Hz^{2/3}$ before wavelength conversion. This project examines the effect of wavelength conversion in a mixed signal environment with an emphasis on reducing network latency without significantly compromising network performance as measured by BER and SFDR.

Bowman Scholar Projects

Using Wavelength Conversion for Routing in Optical Networks

Researcher: Midshipman 1/C Clifford N. Jessop, USN
Advisers: Associate Professor R. Brian Jenkins and Captain Robert J. Voigt, USN
Sponsor: Bowman Scholar Program (BSP)

In optical networks there is currently a need to perform an optical-electrical-optical (O-E-O) conversion at each routing point or node. This introduces latency due to the relatively low speed of the electronic circuitry compared to that of the optical medium. As such, there is a desire to reduce or eliminate the delays associated with the O-E-O conversion by incorporating wavelength conversion. By using wavelength conversion data can remain in an optical format as it is routed through the network thereby reducing latency at each node.

This research investigated the feasibility of using wavelength conversion as a routing tool using computer simulation software and possible construction of an actual wavelength converter. Throughput and reliability were analyzed for a network with and without wavelength conversion. Wavelength conversion was also studied in the context of mixed signal (analog and digital data) networks. A successful simulation assessed whether wavelength conversion increased data transfer rates while maintaining reliability in getting packets successfully routed through the network with lower latency. The investigation further explored attempts to integrate actual wavelength converters into an optical network, checking actual performance against software simulations.

Midshipman Research Project Courses

RF Propagation Measurements

Researchers: Midshipman 1/C Raphael Thalakottur, USN, Midshipman 1/C T. Hunt Hawkins, USN, Midshipman 1/C James Ripley, USN, Midshipman 1/C Katie Gerhard, USN, Midshipman 1/C Duane Willoughby, USN, Midshipman 1/C Justin Wolfe, USN, Midshipman 1/C Kyle Beilke, USN, and Midshipman 1/C Matthew Frederick, USN
Adviser: Commander Thaddeus B. Welch, III, USN

This project involved several midshipmen measuring the effects of placing an antenna very near to the ground or near the human body. This geometry was of concern for tactical forces as well as for civilian cellular, cordless, wireless, and PCS system users and designers (3G and 4G alike). The work included both narrowband and ultra-wideband measurements. Several papers have been published as a result of this work.

Journal (Refereed) Manuscripts

CAMERON, Charles B., Commander, USN, (co-author), "Fast Optical Ray Tracing Using Parallel DSPs", *Institute of Electrical and Electronics Engineers (IEEE) Transactions on Instrumentation and Measurement*, Vol. 55, No. 3, pp. 801-808 (June 2006).

> Optical ray tracing is a computationally intensive operation that is central both to the design of optical systems and to analyzing their performance once built. The authors have previously reported on the use of parallel digital signal processors to reduce the time required to perform ray tracing in analyzing the performance of the MODIS, presently in orbit on multiple spacecraft. The earlier work was incomplete, providing only a conservative estimate of the performance improvement that could be achieved with one to four DSPs. This paper reports on the completed project and extends the earlier work to eight DSPs. As predicted in our earlier paper, not all rays make it through the entire optical system. Many are lost along the way. This is one factor that led to reduced processing time. Another is the use of an optimizing compiler. In this paper we present results showing the effect of each of these two independent factors on the overall processing time. The most significant finding is the extraordinarily linear relationship between the number of DSPs available and the speed of the ray tracing. By using eight DSPs we have reduced the processing time from two weeks to less than one and a half days, an improvement of nearly a whole order of magnitude. Low-cost, high-speed ray tracing is now feasible using off-the-shelf plug-in processor boards.

DU, Yingzi, Assistant Research Professor, IVES, Robert W., Assistant Professor, ETTER, Delores M., Professor and WELCH, III, Thaddeus B., Commander, USN, "Use of One-Dimensional Iris Signatures to Rank Iris Pattern Similarities," *Optical Engineering*, Vol. 45, No. 3, pp. 037201-1 to 037201-10, March 2006.

> A novel approach to iris recognition is proposed in this paper. It generates one-dimensional signatures to rank iris pattern similarities and is translation, rotation, illumination and scale invariant. It is very different from traditional iris recognition systems which typically use two-dimensional iris patterns/codes/signatures for iris identification and recognition and require circular rotation for pattern matching purposes. Also, this approach uses the *Du* measure as a matching mechanism, and generates a set of the most probable matches instead of only the best match. The merit of this method is that it relaxes the requirement of using a major part of the iris. Another merit of our method is that it would allow the iris recognition system to be more tolerant of noise (such as glare introduced by contact lenses or eye glasses). The third merit of this approach is that this method could potentially improve iris identification process computational efficiency.

FIREBAUGH, Samara L., Assistant Professor, (co-author), "Chapter 8: Microelectromechanical Systems for Spacecraft Communications," *Micro Electro Mechanical Systems (MEMS) and Microstructures in Aerospace Applications*, CRC Press, 2005, pp. 149-181.

This chapter on spacecraft communication systems reviews Micro Electro Mechanical Systems (MEMS) applications for both RF and optical based communication systems. One of the most exciting applications of MEMS for microwave communications in spacecraft concerns the implementation of "active aperture phase array antennas." These systems consist of groups of antennas phase-shifted from each other to take advantage of constructive and destructive interference in order to achieve high directionality. Such systems allow for electronically steered radiated and received beams, which have greater agility and will not interfere with the satellites attitude. Phase shifters implemented with micro electro mechanical switches have low insertion loss and require less power than their solid state counterparts, which makes MEMS an enabling technology for lightweight, low-power electronically steerable antennas for small satellites. In optical communication systems, macro-scale electromechanical beam steering subsystems make up a significant fraction of the mass of these systems. This is where MEMS steerable mirrors offer a solution in optical communications, especially for small satellites.

IVES, Robert W., Assistant Professor, DU, Y., Assistant Research Professor, ETTER, Delores M., Professor and WELCH, III, Thaddeus B., Commander, USN, "A Multidisciplinary Approach to Biometrics," *Institute of Electrical and Electronics Engineers (IEEE) Transactions on Education*, Vol. 48, No. 3, pp. 462-472, August 2005.

Biometrics is an emerging field of technology using unique and measurable physical, biological, or behavioral characteristics that can be processed to identify a person. It is a multidisciplinary subject that integrates engineering, statistics, mathematics, computing, psychology, and policy. The need for biometrics can be found in governments, in the military, and in commercial applications. The Electrical Engineering Department at the U.S. Naval Academy has introduced a biometric signal processing course for senior-level undergraduate students and has developed a biometrics lab to support this course. In this paper, the authors present the course content, the newly developed biometric signal processing lab, and the interactive learning process of the biometric course. They discuss some of the challenges that were encountered in implementing the course and how they were overcome. They also provide some feedback from the course assessment.

JENKINS, R. Brian, Associate Professor, (co-author), "Steady-State Noise Analysis of Spontaneous and Stimulated Brillouin Scattering in Optical Fiber," *Institute of Electrical and Electronics Engineers/Optical Society of America IEEE/OSA, Journal of Lightwave Technology,* May 2006.

A steady-state theoretical and experimental analysis was presented for the noise resulting from spontaneous and stimulated Brillouin scattering (SBS) in an optical fiber. Wave equations were derived and solved that described the evolution of the pump and Stokes waves along the fiber. Experiments and numerical results demonstrated the validity of the theory, either when a Stokes wave was launched at the end of the fiber, or when the noise in the Stokes wave was spontaneously generated.

WELCH, III, Thaddeus B., Commander, USN, (co-author), "The Signals and Systems Concept Inventory," *Institute of Electrical and Electronics Engineers (IEEE) Transactions on Education*, vol.48, no.3, pp. 448-61, August 2005.

The signal processing community needs quantitative standardized tools to assess student learning in order to improve teaching methods and satisfy accreditation requirements. The Signals and Systems Concept Inventory (SSCI) is a 25-question multiple-choice exam designed to measure students' understanding of fundamental concepts taught in standard signals and systems curricula. When administered as a pre- and postcourse assessment, the SSCI measures the gain in conceptual understanding as a result of instruction. This paper summarizes the three-year development of this new assessment instrument and presents results

obtained from testing with a pool of over 900 students from seven schools. Initial findings from the SSCI study show that students in traditional lecture courses master approximately 20% of the concepts they do not know prior to the start of the course. Other results highlight the most common student misconceptions and quantify the correlation between signals and systems and prerequisite courses.

Books, Book Chapters, Monographs Magazines and Handbooks

DU, Yingzi, Assistant Research Professor, IVES, Robert W., Assistant Professor, and ETTER, Delores M., Professor, "Iris Recognition," *The Electrical Engineering Handbook,* 3rd Edition, Boca Raton, FL: CRC Press, 2006, pp. 25-1 to 25-10.

The iris is a valuable biometric for use in identification, with distinctive texture that remains stable throughout life. The striations, filaments, and rings that make up the iris pattern are very unique to each person. Because of its uniqueness to an individual, it can provide identification with very high confidence through large databases. Compared with other biometric features such as face and fingerprint, iris patterns are more stable and reliable. Iris recognition systems are non-invasive to their users, but require a cooperative subject.

IVES, Robert W., Assistant Professor, MCGOWAN, Joseph C., Captain, USN, ETTER, Delores, M., Professor, and DU, Y., Assistant Research Professor, "Signal Processing Outreach at the United States Naval Academy," *Institute of Electrical and Electronics Engineers (IEEE) Signal Processing Magazine*, Vol. 23, No. 2, pp. 10-16, March 2006.

The United States Naval Academy provides an outreach program to rising high school seniors called "Summer Seminar." This program offers the opportunity for the students from all 50 states to visit the Naval Academy for one of three six-day sessions during the summer, experiencing life as a midshipman, both academically and otherwise. Their experiences attempt to provide them with enough information to determine if the Naval Academy is the right choice for their undergraduate education, and whether a commission as a Navy or Marine Corps officer might be the right career path for them.

The academic portion of Summer Seminar provides a broad overview of the academic programs offered to matriculating students. The summer seminar "campers" select 8 workshops from among the 20+ offered. These two-hour sessions are designed to expose prospective students to topics in various fields and also to provide, where practical, demonstrations and hands-on experience. A total of 1829 high school students attended the program in 2004, and approximately 360 of these attended the workshop on electrical engineering. The primary focus of the electrical engineering workshop was signal processing, including introductory material, practical exercises and demonstrations. Here, we document the outreach to these students that occurred during the summer of 2004.

IVES, Robert W., Assistant Professor and ETTER, Delores M., Professor, "Introduction to Biometrics", *The Electrical Engineering Handbook*, 3rd Edition, Boca Raton, FL: CRC Press, 2006, pp. 24-1 to 24-8.

Biometrics is a relatively new area of technology that uses unique and measurable physical, biological, or behavioral traits of people to establish or to verify their identification. Identification and verification are two separate operations. In identification, the biometric system asks and attempts to answer the question "Who is this person?" by collecting and comparing biometric sample(s) from an individual and comparing it to the information contained in its database. This is a *one-to-many* search. With verification, the biometric system asks and attempts to answer the question "Is this Joe?" Here, Joe claims he is Joe and submits a biometric sample(s) which is compared to the information contained in the database for Joe. This is a *one-to-one* search. Biometrics is most often used to perform identity verification for authorized access to computer networks or secure facilities. The physical attributes typically used include face, iris, fingerprints, hand geometry, handwriting, and voice. Compared to common identification methods, such as

identification (ID) cards, personal identification numbers (PINs) or passwords, biometrics can be more convenient for users, has lower costs for businesses, reduces fraud, and is more secure.

There is need for biometrics in federal, state and local governments, in the military, and in commercial applications. Biometrics has been used in the criminal justice system, in U.S. immigration and naturalization services, and in place of passwords or keys for e-commerce. In 2001, the *MIT Technology Review* named biometrics "one of the top ten emerging technologies that will change the world." Since September 11th, 2001, a heightened awareness of security issues is driving the adoption of biometrics within numerous application environments. Some considerations for choosing a biometric system to use, as well as a description of some of the more widely used biometrics, is presented in the following sections.

IVES, R. W., Assistant Professor and ETTER, Delores, M. Professor, "Computing Environments for DSP", *The Electrical Engineering Handbook*, 3rd Edition, Boca Raton, FL: CRC Press, 2006, pp. 23-1 to 23-14.

Computing environments provided by software tools allow users to design, simulate, and implement digital signal processing (DSP) techniques with speed, accuracy, and confidence. With access to libraries of high-performance algorithms and access to advanced visualization capabilities, we can design and analyze systems using the equations and notations that we used to think about for signal processing problems. We do not have to translate the equations and techniques into a different notation and syntax. The graphics interface provides an integral part of this design environment, and is accessible from any point within our algorithms. Within this type of computing environment, we are more productive. But, even more important, we develop better solutions because we have so many more tools for analyzing solutions, for experimenting with "what if" questions, and for developing extensive simulations to test our solutions. To illustrate the power of these environments, we present a brief description of MATLAB®, one of the most popular technical computing environments in both industry and academia, and then present five examples that use MATLAB®.

WELCH, III, Thaddeus B., Commander, USN, (co-author), "Real-time Digital Signal Processing from MATLAB® to C with the TMS320C6x DSK," CRC Press, Taylor & Francis Group, Boca Raton, FL, 2006

From personal music players to anti-lock brakes and advanced digital flight controllers, the demand for real-time digital signal processing (DSP) continues to grow. Mastering real-time DSP is one of the most challenging and time-consuming pursuits in the field, exacerbated by the lack of a resource that solidly bridges the gap between theory and practice. Recognizing that there is a better way forward, this book collects all of the necessary tools in a single, field-tested source of unrivaled authority. The authors seamlessly integrate theory with easy-to-use, inexpensive hardware and software tools in an approachable and hands-on manner. Using abundant examples and exercises in a step-by-step approach, they work from familiar interfaces such as MATLAB® to running algorithms in real-time on industry-standard DSP hardware. For each concept, the book uses a four-step methodology: a brief review of relevant theory; demonstration of the concept in winDSK6, an easy-to-use software tool; explanation and demonstration of MATLAB® techniques for implementation; and explanation of the necessary C code to implement the algorithms in real time.

Conference Proceedings

IVES, Robert W., Assistant Professor, KENNELL, L., Assistant Research Professor, GAUNT, Ruth M., Midshipman 1/C, USN, and ETTER, Delores, M., Professor, "Iris Segmentation for Recognition using Local Statistics," *Proceedings of the 39th Asilomar Conference on Signals, Systems and Computers*, pp.859-863, Pacific Grove, CA, November 2005.

Iris recognition is a proven, accurate means to identify people. Commercial iris recognition systems are currently employed to allow passengers in some airports to be rapidly processed through security, to allow access to secure areas, and for secure access to computer networks. With the growing employment of iris recognition systems and associated research to support this, the need for large databases of iris images is

growing. If required storage space is not adequate for these images, compression is an alternative. It allows a reduction in the space needed to store these iris images, although it may be at a cost in some amount of information lost in the process. This paper investigates the effects of image compression on iris recognition. Compression is performed using JPEG2000, and the iris recognition algorithm used is based on several methods, including the Daugman algorithm.

IVES, Robert W., Assistant Professor, DU, Y., Assistant Research Professor, SCHULTZ, Robert C., Lieutenant, USN, and ETTER, Delores M., Professor, "The New Biometric Signal Processing Laboratory at the United States Naval Academy," *Proceedings of the 2005 Institute of Electrical and Electronics Engineers (IEEE) Frontiers in Education Conference*, Indianapolis, IN, October 2005, pp. S1G-6 to S1G-7.

A biometric is a distinct, robust, and measurable physical and/or physiological characteristic of a person which can be used to identify, or verify their identity. Additionally, the term biometrics refers to the automated recognition of an individual using one or more of these characteristics. The more commonly used biometrics includes fingerprints, face, and iris. Biometrics has proven to be a solution to a number of security-related applications where accurate identification or verification of individuals is required. The technology continues to evolve at a rapid pace, and efforts have been made to incorporate the study of this field into our undergraduate curriculum. To support the education of our undergraduates in biometric theories and technologies, we have developed a biometric signal processing laboratory in the Electrical Engineering Department at the United States Naval Academy. This paper summarizes the equipment and activities associated with this lab.

JENKINS, R. Brian, Associate Professor, and VOIGT, Robert J., Captain, USN, "A Mixed Signal DWDM Local Area Network Using Bi-Directional Add Drop Multiplexers," *Avionics Fiber Optics and Photonics Conference*, 20-22 September 2005, Minneapolis, MN.

A mesh architecture is proposed for a bi-directional dense wave division multiplexed (DWDM) network using a novel bi-directional add drop multiplexer (BADM) which supports a mixed signal environment at high data rates.

KENNELL, Lauren R., Assistant Research Professor, IVES, Robert W., Assistant Professor, and GAUNT, Ruth M., Midshipman 1/C, USN, "Binary Morphology and Local Statistics Applied to Iris Segmentation for Recognition," *2006 Institute of Electrical and Electronics Engineers (IEEE) International Conference on Image Processing*, accepted for publication.

One of the first steps in iris recognition is isolating (or *segmenting*) the iris from an image of the subject's eye area. This paper investigates new approaches for locating the pupil (inner) and limbic (outer) boundaries of the iris, namely a binary morphology and "center of mass" technique for the pupil boundary, and a local statistics approach for the limbic boundary. The methodology and results are presented using images from the University of Bath iris database.

RAKVIC, Ryan R. Assistant Professor, (co-author), "Multiple Instruction Stream Processor," *36th Annual International Symposium on Computer Architecture*, pp. 114-127, June 2006

Microprocessor design is undergoing a major paradigm shift towards multi-core designs, in anticipation that future performance gains will come from exploiting thread level parallelism in the software. To support this trend, we present a novel processor architecture called the Multiple Instruction Stream Processing (MISP) architecture. MISP introduces the sequencer as a new category of architectural resource, and defines a canonical set of instructions to support user-level inter-sequencer signaling and asynchronous control transfer. MISP allows an application program to directly manage user-level threads without OS intervention.

By supporting the classic cache-coherent shared-memory programming model, MISP does not require a radical shift in the multithreaded programming paradigm. This paper describes the design and evaluation of the MISP architecture for the IA-32 family of microprocessors. Using a research prototype MISP processor built on an IA-32-based multiprocessor system equipped with special firmware, we demonstrate the feasibility of implementing the MISP architecture.

The utility of MISP is examined by (1) assessing the key architectural tradeoffs of the MISP architecture design and (2) showing how legacy multithreaded applications can be migrated to MISP with relative ease.

SALEM, Thomas E., Assistant Professor, (co-author), "Technique for Die Surface Temperature Measurement of High-Voltage Power Electronic Components using Coated Thermocouple Probes", *2006 Electrical and Electronics Engineers (IEEE) IEEE Instrumentation and Measurement Technology Conference*, 24-27 April 2006, pp. 651-654.

The performance capabilities of high-voltage high-power systems are significantly impacted by the thermal limitations of power electronic components. To address this issue, numerous current research efforts have been conducted to examine advanced packaging materials and structures as well as novel cooling techniques. Critical to the success of this work is the accurate measurement and characterization of the thermal characteristics of the power electronic components. This paper presents a methodology and assessment of using coated thermocouple probes for measuring the die surface temperature of active high-voltage power electronic components.

SALEM, Thomas E., Assistant Professor, (co-author), "Fabrication and Practical Considerations of a Flyback Transformer for use in High Pulsed-Power Applications," *38th Electrical and Electronics Engineers (IEEE) Southeastern Symposium on System Theory*, March 2006, pp. 397-400.

The design and use of the flyback converter topology in high voltage applications is common. Most often these systems are low power units such as that found in a television electron beam circuit. However, little is recorded in the literature on the design and use of this topology for high, pulsed-power applications. These pulsed circuits have a variety of end uses, including anti-terrorism. For example, work has recently been reported on the use of high-energy, pulsed power to destroy anthrax bacteria [1-2]. This paper presents details on the design and fabrication of a high voltage flyback transformer for use in high, pulsed-power circuits. Experimental data from a 4.8 kW pulsed-power flyback converter is presented which documents the efficacy of the transformer construction.

SALEM, Thomas E., Assistant Professor, (co-author), "Radio Frequency Directed Energy Against Improvised Explosive Devices (IEDs) (RAID)", *8th Annual Directed Energy Symposium*, November 2005. (Published – CLASSIFIED).

Improvised Explosive Devices (IEDs) are a deadly threat to civilians and military forces alike. Often the "triggering elements" for these devices are some form of commercial Radio Frequency (RF) transceiver, such as a cordless phone, pager, car alarm, etc., or some form of non RF device, such as an electronics watch/timer or infrared motion sensor. Since many IEDs contain electronics it may be possible to irradiate them with sufficient levels of Radio Frequency Directed Energy (RF DE) to upset and/or damage the electronics sufficient to pre-fire or dud the device. To determine the power/energy requirements for a RAID (RF Against IED) system to neutralize an IED one must first know the RF field level and/or power density required on the incident to produce the desired effect.

This paper describes an investigation conducted by the Army Research Laboratory (ARL) to determine if RF DE could upset and/or damage the electronic sensor/triggers in an IED sufficient to produce pre-detonation and/or duding of the device. RF effects experiments were conducted on representative sensors/triggers to upset and/or damage the devices. Both continuous wave (CW) and pulsed CW RF experiments were conducted over a wide frequency range. A discussion of the experimental results and how they were used to develop power/energy and system requirements for a breadboard RAID system will

be presented. Finally the presentation concludes with the development of the bread board and its potential effective range against selected sensors/triggers.

SCHULTZ, Robert C., Lieutenant, USN, and IVES, Robert W., Assistant Professor, "Biometric Data Acquisition using MATLAB GUIs," *Proceedings of the 2005 Institute of Electrical and Electronics Engineers (IEEE) Frontiers in Education Conference*, Indianapolis, IN, October 2005, pp. S1G-1 to S1G-5.

The use of iris patterns, fingerprints, facial characteristics and other biometrics for identification is becoming more common every day. This has led to the incorporation of biometric topics in courses at many colleges throughout the world. Developing practical laboratory exercises to augment course lectures is enhanced when the students have the ability to work with actual biometric data. Although the hardware for using biometrics is available at a reasonable cost, most commercial products do not readily output the raw data that is desired for laboratory or research environments. Even if the data can be acquired, a system of storage and retrieval that incorporates unique information related to the data is needed. Finally, the acquisition of biometric data introduces human research and privacy concerns that must be addressed by the institution. Using MATLAB with its Image Acquisition Toolbox, a system was developed to easily capture biometrics and store them with pertinent information for laboratory exercises, student research and faculty research. Concerns involving human subjects and privacy, the challenges associated with developing a biometric database, and one solution to acquiring biometric data for use in student laboratories are discussed.

Presentations at Professional Meetings and Conferences

IVES, Robert W., Assistant Professor, "Iris Recognition Research at the U.S. Naval Academy," National Institute of Standard and Technology (NIST) Iris Challenge Evaluation (ICE) Kick-off Meeting, Annapolis, MD, 17 August 2005.

IVES, Robert W., Assistant Professor, "A One-Dimensional Approach to Iris Recognition: The RECON System," the Iridian Corporation, Moorestown, NJ, 03 November 2005.

IVES, Robert W., Assistant Professor, "Iris Recognition Research at the U.S. Naval Academy," 8th Intelligence Technical Innovation Center (ITIC) Biometrics Colloquium, Annapolis, MD, 10 March 2006.

JENKINS, R. Brian, Associate Professor and VOIGT, Robert J., Captain, USN "A Mixed Signal DWDM Local Area Network Using Bi-Directional Add Drop Multiplexers," Avionics Fiber Optics and Photonics Conference, Minneapolis, MN, presentation TuC1, 20-22 September 2005.

JESSOP, Clifford N., Midshipman 1/C, USN, JENKINS, R. Brian, Associate Professor, and VOIGT, Robert J., Captain, USN, "Using All-Optical Wavelength Conversion for Routing in Optical Local Area Networks," National Conference On Undergraduate Research (NCUR) 2006, The University of North Carolina at Asheville, Asheville, NC, 6-8 April 2006.

KENNELL, Lauren R., Assistant Research Professor, "Iris Segmentation for Recognition Using Local Statistics," 39th Annual Asilomar Conference on Signals, Systems, and Engineering, Monterey, CA, 31 October 2005.

KENNELL, Lauren R., Assistant Research Professor, "Binary Morphology and Local Statistics Applied to Iris Segmentation for Recognition," DCI Postdoctoral Conference, McLean, VA, 18 April 2006.

Morrow, M. G., WELCH, III, Thaddeus B., Commander, USN, and Wright, C. H. G., "A Host Port Interface Board to Enhance the TMS320C6713 DSK", Proceedings of the 2006 Institute of Electrical and Electronics Engineers (IEEE) Int. Conference on Acoustics, Speech and Signal Processing, Toulouse, France, May 2006.

THALAKOTTUR, Raphael, Midshipman 1/C, USN, HAWKINS, T. Hunt, Midshipman 1/C, USN, RIPLEY, James, Midshipman 1/C, USN, WELCH, III, Thaddeus B., Commander, USN, GERHARD, Katie, Midshipman 1/C, USN, WILLOUGHBY, Duane, Midshipman 1/C, USN, WOLFE, Justin, Midshipman 1/C, USN, BEILKE, Kyle, Midshipman 1/C, USN, and FREDERICK, Matthew, Midshipman 1/C, USN, "ULTRA WIDEBAND … THE MOVIE!", Proceedings of the 2006 Wireless Personal Communications Symposium, Blacksburg, VA, June 2006.