Weapons and Systems Engineering Department

Professor Carl E. Wick
Chair

Research within the Weapons and Systems Engineering Department continues to provide the faculty with an opportunity to grow professionally and to keep abreast of rapidly advancing systems technology. In addition, every graduating Systems Engineering major participates in research, design, and development projects for the purpose of realizing practical applications of some of the theory which they have studied.

Every faculty member, both civilian and military, either participates in research in areas of interest to U.S. Navy or supports midshipmen research programs in an advisory capacity. Faculty research areas currently include controls, magnetic bearings, metrology, robotics, ship power systems, and system identification.

This year there were two Trident Scholars in the Systems Engineering Department. The scholars engaged in an extensive research project in lieu of several courses. Strong emphasis continues on the faculty-midshipman relationship during the individual research oriented capstone design course. Each midshipman is assigned both an administrative and a technical adviser. These advisers not only provide support of a technical nature, but also emphasize planning, scheduling, and effective oral and written presentation. Typical examples of midshipmen research projects include development of autonomous carts and boats, automatic target detection, tracking, and control.

Funding for research continues to be diverse. This year sponsors included the Naval Academy Research Council (NARC), the Office of Naval Research (ONR), the Naval Research Lab (NRL), the Naval Surface Warfare Center (NSWC), and the National Institute of Standards and Technology (NIST).

Sponsored Research

Atlantic Center for the Innovative Design of Small Ships

Researcher: Associate Professor Bradley E. Bishop
Sponsor: Office of Naval Research (ONR)

Novel hull designs and locomotive capabilities for littoral craft will require substantial automation in order to achieve minimum manning, maximal power efficiency and optimal performance. Additionally, automation can be used to enhance safety and minimize environmental impact. The primary focus of this project is to provide an updated toolbox of systems engineering methods for enhanced littoral operations.

This effort has three distinct components. Component I involves coordination of a swarm or platoon of cooperating autonomous surface vessels for enhancing security and providing both reconnaissance and force projection. Component II involves the application of control theory to stability and control problems for small craft in littoral zones. Component III involves design, construction and fielding of a fully instrumented autonomous surface vessel.

Test Generation for Embedded Control Systems

Researcher: Assistant Professor Joel M. Esposito
Sponsor: Naval Academy Research Council (NARC)

The idea is to create an algorithm whose inputs are: a model of the control system being tested, along with initial conditions; and the specification which it is being tested against. The output of the algorithm is a set of open loop test input functions which represent a minimal set of test scenarios required to determine with within some confidence interval if the system meets the specification. The primary motivation behind developing such a method is to avoid the time, expense and inconclusiveness of trial and error testing by using automated rigorous tools to guide the design process. The notion of a test generator and test adequacy criteria, defined for software testing, are formalized for control systems in terms of the maximum principle. A method from randomized robot motion planning, Rapidly Exploring Random Trees (RRT) is modified and applied to this problem. Modifications are centered around the difficulties associated with testing uncontrollable systems.

Distributed Manipulation of Large Objects on the Water by Swarms of Autonomous Surface Vessels

Researcher: Assistant Professor Joel M. Esposito
Sponsor: Office of Naval Research (ONR)

The goal of this project is to allow a single human operator to control and supervise the on-water manipulation of large objects using swarms of autonomous surface vessels. Swarms – large groups of relatively simple and cheap robots working in concert without a centralized decision maker – have been a popular area of research over the past few years. However, few works actually address the issue of how swarms can affect changes in their environment. On-water manipulation of large objects by a swarm of small autonomous vehicles is a relatively novel area of investigation with naval applications to marine ordinance disposal, transportation of disabled ships, and assembly of large marine structures such as positioning sonar arrays for littoral surveillance or construction of off-shore platforms and bases. Aside from these direct applications, the methodology developed will have indirect application to land-based robot swarms, swarm reconnaissance and exploration missions, and micro-assembly tasks.

An H-Infinity-Based Detection and Tracking Method for Underwater Sensor Systems

Researchers: Associate Professor Richard T. O'Brien, Jr. and Associate Professor Kiriakos Kiriakidis
Sponsor: Office of Naval Research (ONR)

This project, having completed its second year and still in progress, focused on two topics: (1) the design of real-time target tracking and detection algorithms based on worst-case minimization and (2) performance enhancement and convergence analysis of these algorithms, particularly, in the case of arbitrary array geometry and broadband signals. The development of target information algorithms will proceed in three stages: (a) assuming target detection, a target parameter estimator will be developed using multiple models for the signal and the target kinematics, (b) the estimator will be modified to incorporate target detection, and (c) a time-varying parameter estimator for the signal will be developed, but without an underlying kinematic model for the target. To reduce the estimation error, the minimization of a weighted worst-case performance criterion will be investigated. To provide for analysis of the algorithms, recent results on time-varying stochastic regression will be extend to the proposed robust estimator. The "transition potential" of the algorithm will be evaluated on a group of autonomous vehicles that, equipped with sonar sensors, form an array of variable and potentially adaptable geometry.

Pulse-Width Modulated Control for Cold Water Diver Catalytic Heater Temperature Control System

Researcher: Professor Kenneth A. Knowles
Sponsor: Office of Naval Research (ONR)

Under the Office of Naval Research (ONR) funding, a laboratory prototype heating system for closed-circuit hot water suits using hydrogen catalytic reactions in a semi-closed circuit was designed, fabricated, and tested in the Hydrospace Laboratory at the Coastal Systems Station in Panama City, FL. Unmanned and manned testing and evaluation verified that satisfactory performance of the heater can be achieved for two to six divers operating in a 0°C (32°F) environment, but undesirable time lags in correcting temperature were experienced for varying heat loads as the number of connected divers was varied. An improved microprocessor heater control system has since been developed and tested using several small prototype systems. This proof of concept heater controller was designed to verify the use of a small microprocessor circuit with pulse-width modulated (PWM) control valves in controlling the heater and suit water temperatures. The PWM valves greatly simplified the control hardware. In the process of developing this controller, it was discovered that a hot water mixing strategy could eliminate the undesirable temperature control time lags experienced in the original system.

Electric Helicopter Surveillance Vehicle Demonstration

Researchers: Professor Kenneth A. Knowles
and Dr. David Brown (Defense Acquisition University, DAU)
Sponsor: Office of Naval Research (ONR)

The objective of Electric Helicopter Surveillance Vehicle is to demonstrate close line-of-sight control for direct support of unmanned vehicles for Special Forces and front line Marine Corps and Army combat troops. Operations in Afghanistan demonstrated the critical role that unmanned vehicles play in current and future operations. However, deficiencies were identified in that most current Unmanned Air Vehicle (UAV) systems are controlled by operators at remote locations. Front line combat troops do not have direct access to the imagery from onboard sensors. They also must attempt to talk remote operators onto targets to obtain reconnaissance or direct fire support. This project will build and demonstrate a small scale commercial off-the-shelf (COS) advanced technology demonstration system that will permit an Unmanned Rotocraft Vehicle (URV) to be controlled by two different operators. The primary operator will launch and recover the URV simulating the remote operator used in current applications. A second operator will take control of the URV while in flight and use it to perform direct support reconnaissance. This operator will use a personal computer with menu flight control and real time video display provided by a camera onboard the URV. The shared control concept is applicable to a wide variety of future air, ground and sea unmanned vehicles. The remote vision system has been demonstrated. A small test vehicle has been constructed and is undergoing flight tests. The larger vehicle has been constructed and is undergoing pre-flight tests. Computer generation of flight control signals has been demonstrated. Additional required parts and equipment are on-order. This is an on-going effort that will be funded through the next academic year.

Single-Snapshot Robust Direction Finding

Researchers: Associate Professor Richard T. O'Brien, Jr. and Associate Professor Kiriakos Kirikidis
Sponsor: Office of Naval Research (ONR)

The project will focused on two topics: (1) the design of real-time target tracking and detection algorithms based on worst-case minimization and (2) performance enhancement and convergence analysis of these algorithms, particularly, in the case of arbitrary array geometry and broadband signals. The development of target information algorithms proceeded in three stages: (a) assuming target detection, a target parameter estimator was developed using multiple models for the signal and the target kinematics, (b) the estimator was modified to incorporate target detection, and (c) a time-varying parameter estimator for the signal was developed, but without an underlying kinematic model for the target. To reduce the estimation error, the minimization of a weighted worst-case performance criterion was investigated. To provide for analysis of the algorithms, recent results on time-varying stochastic regression was extended to the proposed robust estimator. The "transition potential" of the algorithm was

evaluated on a group of autonomous vehicles that, equipped with sonar sensors, form an array of variable and potentially adaptable geometry.

Atlantic Center for the Innovative Design and Control of Small Ships: Vision-based Wave Sensing

Researchers: Associate Professor Jennifer K. Waters (Naval Architecture and Ocean Engineering Department) and Associate Professor Jenelle A. Piepmeier
Sponsor: Office of Naval Research (ONR)

The Atlantic Center for Innovative Design is a consortium of individuals from Stevens Institute of Technology, University College of London, Webb Institute, the U.S. Naval Academy, and a number of industry partners. The Center proposed to address and meet the Navy's new and emerging needs in the littoral zone by focusing on two key areas. The current research investigated vision-based sensing methods to provide sea state estimation for improved sea-keeping. Work during the summer of 2004 investigated the feasibility of a vision-based wave sensing approach that was able to determine pertinent wave characteristics, such as slope, height, and frequency. A stereo vision-based system was successfully applied to measure the water surface of the Severn River in Annapolis, Maryland. Surface plots were generated and significant wave heights were computed for a variety of camera angles and resolutions. Validation of this data was obtained by a conventional wave probe. Work during the fall of 2004 included testing at Carderock NSWC wind-wave tank. During the spring of 2005 the work focused on vessel wake studies at the U. S. Naval Academy.

Flight Control Development for the Samara Rotary/Fixed Wing Micro Air Vehicle

Researcher: Associate Professor George E. Piper
Sponsor: Naval Research Laboratory (NRL)

The Naval Research Laboratory (NRL) developed a group of micro air vehicle (MAV) concepts intended for operation in urban or other confined environments. Primary flight requirements for these MAVs are low speed maneuverability, vertical takeoff and landing, and the potential for hovering. In particular there was interest in an MAV that could land or "perch" in remote locations and then take to the air again. This interest led to the development of a novel rotary/fixed wing air frame configuration called Samara. The novel Samara airframe configuration possessed unique flight characteristics and control issues. Understanding the flight phenomenon of this vehicle was critical for the development of a flight control system. The work continues with NRL to characterize the flight dynamics and to develop practical flight control system for the Samara aircraft.

Electric Ship Integration

Researchers: Associate Professor Edwin L. Zivi
and Associate Professor John G. Ciezki (Electrical Engineering Department)
Sponsor: Office of Naval Research (ONR)

This research supports the U.S. Navy's push towards the development of an Electric Warship. The Naval Academy investigators were part of a collaborative effort that included faculty from the Massachusetts Institute of Technology, Purdue University, and the University of Missouri at Rolla. More specifically, the effort involved the integration of research, analyses, software and hardware tools, monographs, and curricula to support multidisciplinary ship design, power system analysis, and automation engineering. The Naval Academy leads the Automation and Systems Engineering thrust and has established an automation systems research laboratory located in Maury Hall. Over the last two academic years, this distributed control prototyping environment was used to support faculty research, one Trident Project, two Bowman Scholar Projects, and four Senior Design Projects. A Systems Engineering automation course curriculum including lecture, laboratory and student projects was defined and preparation of course materials, including a textbook in the form of an automation monograph is underway. A complimentary Electrical Engineering power systems course for non-EE majors was outlined and preparation of a teaching manuscript was initiated. This material supported current core courses as well as future multidisciplinary engineering offerings. The primary recent accomplishment involved the collaborative derivation of a novel, fault

tolerant Digital Delta-Hysteresis Regulation (DDHR) motor drive controller. Experimental validation at the University of Missouri at Rolla demonstrated that motor drive systems can maintain relatively accurate control of phase currents in the event of the loss of all phase current and rotor position sensors. Within the scheme, line currents were reconstructed using knowledge of the DC-link current and switching states.

Distributed Automation Design for Survivability

Researcher: Associate Professor Edwin L. Zivi
Sponsor: Office of Naval Research (ONR)

This research involved the derivation and demonstration of novel "system of systems" design methods, metrics and tools in collaboration with Purdue University, the MIT Ocean Engineering Department, and the Georgia Institute of Technology Aerospace Systems Design Laboratory. This methodology emphasized design attributes which provide continuity of vital services. Specifically, operability was mathematically defined as the system's ability to provide continuity of distributed services to vital loads with respect to a particular casualty induced damage disruption. By extension, dependability has been defined in terms of operability over a distribution of likely damage disruption scenarios. A system modeling framework involving dynamically interdependent networks for AC electrical power, DC zonal distribution, fluid transport thermal management, automation, and communication as well and spatial arrangements were defined. Preliminary system models and associated numerical simulation models have recently demonstrated the capability to use evolutionary computing to quantitatively assess operability and dependability of alternative designs. Ongoing research involved the refinement of the system design models and subsequent exploration of the design space. In particular, evolutionary computing techniques can be used to search for system vulnerabilities.

Electric Ship Research and Development Consortium Control Architecture Demonstration

Researchers: Associate Professor Edwin L. Zivi
and Associate Professor John G. Ciezki (Electrical Engineering Department)
Sponsor: Office of Naval Research (ONR)

This investigation focused on the derivation and proof-of-concept simulation based assessment of alternative electrical power system architectures, control strategies and control algorithms for future electric warships. For the first time, a practical method for determining regions of asymptotic stability for high-order non-linear systems subject to large scale disruptions was developed. While methods to accomplish this for small scale systems have been known for some time, the application of these methods to arbitrarily large non-linear systems was proven illusive. This new methodology used genetic optimization to search for the least conservative Lyapunov stability bounds. A second thrust investigated hierarchically structured control algorithms to achieve superior fault tolerance. Specifically, supervisory control was augmented by intermediate and distributed component-level controls which incorporated graceful degradation. The primary objective was an electrical system which could self-assess damage and dynamically reconfigure components and networks in order to sustain power to critical loads in the event of massive damage. These designs must be robust with respect to uncertain parameters and system configuration due to real-time response constraints and the fact that exact damage scenarios cannot be determined a priori.

Independent Research

Motion Control of Swarm Robots for Robust Wireless Communication

Researcher: Assistant Professor Joel M. Esposito

Swarms of robots must employ distributed motion control algorithms to effectively achieve their objectives; however many objectives cannot be accomplished without some communication and coordination among the swarm members. While completing their primary task the robots must therefore also maintain a robust mobile wireless network among themselves. For the purposes of this project, doing so implies each robot would maintain proximity and line of sight to two or more swarm members at all times. The project created individual control laws

for range and line of sight, an algorithm for composing the velocities to achieve the many disparate objectives, and an analysis of the natural topology of the emerging configurations.

Tracking Control of an Under Actuated Unmanned Underwater Vehicle

Researchers: Assistant Professor Matthew G. Feemster

A robust position tracking controller was investigated for an autonomous, underactuated, unmanned underwater vehicle (UUV). Specifically, the proposed controller forced the three dimensional (*i.e.*, longitudinal, latitudinal, and depth) position tracking error to within an arbitrarily small region about zero (i.e., global exponential uniformly ultimately bounded tracking) through the utilization of one translational and three orientation actuators. Therefore, the proposed methodology held special appeal to such underactuated applications as the omni-directional intelligent navigators (ODINs) by extending capabilities to include changes in vehicle depth. In addition, uncertainty in such parameters as vehicle inertia and hydrodynamic damping forces were compensated through a robust control structure. Simulation results were provided to illustrate performance and details of the controller.

Tethered Swim-Out Capture Vehicle for AUV's

Researcher: Professor Kenneth A. Knowles

The objective of this project was to develop a low-cost proof-of-concept demonstration tethered device that would swim out of a torpedo tube simulator to locate and attach, under operator control, to another body (simulating an Autonomous Underwater Vehicle) for retrieval back into the torpedo tube. It was the overall objective of this research to prove a simpler and more robust method of retrieving AUV's than currently utilized. Low-cost bilge pumps provided thrustor propulsive power for the demonstration unit.

Bang-Bang Control of Double Integrator Systems

Researcher: Associate Professor Richard T. O'Brien, Jr.

The bang-bang controller comprised an inner velocity control loop and an outer position control loop. Due to the choice of the control signals, the velocity at each sample time was independent of the position control signal. In the inner loop, a discrete-time compensator was used to regulate velocity and reject step disturbance in acceleration due to forces or moments on the system. The outer loop produced a pre-determined, piecewise constant (bang-bang) signal proportional to the position tracking error. The position control signal defined the desired inter-sample position and velocity behavior and generalized the constant inter-sample behavior associated with a zero-order hold. In an effort to quantify the robustness of this controller for double-integrator systems with additional (non-integrator) dynamics, the response of higher order systems of this type was modeled in terms of the additional (non-integrator) dynamics. This work admitted extensions to robustness, analysis and design.

Trident Scholar Projects

Direction of Arrival Estimation Using a Reconfigurable Array

Researcher: Midshipman 1/C Danica L. Adams, USN
Advisers: Associate Professor Richard T. O'Brien, Jr. and Associate Professor Kiriakos Kiriakidis
Sponsor: Office of Naval Research (ONR)

The goal of this project was to create a reconfigurable array that can determine the direction of arrival of a target. This goal was accomplished by using existing algorithms, in conjunction with redefining the assumed geometry of the array. These algorithms were modified to work with arrays that have the ability to move or change shape. The project investigated the effect of array rotation on the size of the data needed for the algorithm. It also examined the effect of changing the geometry from a purely linear array to an array that has two linear parts.

For demonstration purposes, ultrasonic sensors were used. Prior to implementing them, the proposed modifications to the geometry were simulated using a computer model. After the simulations were complete, the modifications were tested on the actual array. The first geometry examined with actual sensors was the linear array. The geometries investigated were those consisting of half of the array rotating such that the array formed an angle. These geometries were tested using the modifications made to the assumed geometry of the array within the algorithm. The modification of the assumed geometry allowed for different geometries to be tested.

This project correlates with the research that the Office of Naval Research (ONR) is funding in non-conventional arrays. The results of this Trident Project investigation led to further research and development of sonar arrays that may have practical applications for the Navy. An area of comparable research is that involving the resolution of ambiguities that occur when determining a direction of approach. The results obtained in this Trident Project also fit into this area of research in both the Navy and the civilian world.

Artificial Potential Field Controllers for Robust Communication in a Network of Swarm Robots

Researcher: Midshipman 1/C Thomas W. Dunbar, USN
Adviser: Assistant Professor Joel M. Esposito

An active area of research in the robotics community is "swarm control," where many simple robots work together to execute tasks which are beyond the capability of any single robot acting alone. Yet in order for the swarm members to work together effectively they must maintain a reliable and robust wireless communication network among them. The goal of this Trident Project was to create motion control laws which fulfill the dual and sometimes conflicting requirements of executing a primary mission (e.g. search and rescue) while maintaining a robust mobile wireless communication network among the swarm members. The success or failure in sending or receiving a wireless message was inherently probabilistic, but the odds of successfully relaying a message increase considerably based upon the spatial arrangement of the swarm members. This imposed a variety of constraints on each robot's motion, each robot sending a message should: (1) maintain a line of sight to the receiving robot (esp. in an environment like a cave or bunker with dense walls); (2) stay within close proximity of the receiving robot (the range is dictated by the power of the transmitter); (3) in addition, the overall redundancy of the swarm was increased by maintaining requirements 1 and 2 for two or more receiving robots simultaneously.

To this end, several artificial potential field controllers – a popular method of robotic control - were developed and simulated to determine their success in controlling the swarm. At a higher level, the project addressed the challenge of how to compose a motion control law to achieve the primary mission while maintaining as many communication restraints as possible. This project included a proof-of-concept implementation of the motion control law on real robots. Secondly, this project simulated and statistically analyzed the controller to determine the effectiveness at achieving the primary mission and maintaining a robust communication network. Several variants of the controller were also analyzed to determine their relative effectiveness.

Midshipman Research Course Projects

Swarm Technology SAR: Obstacle Avoidance, Localization and Platform Design

Researcher: Midshipman 1/C Christopher Lollini, USN
Adviser: Associate Professor Bradley E. Bishop

Robotic search vehicles capable of traversing terrain deemed unsafe for human intervention is an accepted practice in today's search and rescue community. Though unmanned vehicles are not yet capable of rescuing human victims, their capacity as search units is unmatched. Electronic sensors that see what a human eye cannot, robust design, and low cost of loss are all contributing factors to the robotic search advantage. A new approach to the search process was the use of coordinated swarms of unmanned vehicles capable of nearly autonomous collaborative work. This project involved development of a user interface and computational platform, a novel operational paradigm and a platform for search and rescue, including a localization system based on optical mouse components. The intent was to develop new techniques that increase speed of delivery and quality of information to increase

victim survival rates in disaster areas deemed dangerous for human searchers through coordinated swarm techniques.

Unmanned Aerial Vehicle (UAV) Control and Navigation Test Bed

Researcher: Midshipman 1/C Darren Jacques, USN
Adviser: Associate Professor George E. Piper

The goal of this project was to build a hardware-in-the-loop simulation to facilitate the development and testing of the avionics system for the Systems Engineering UAV Project. The UAV test bed consisted of a PC computer running simulation software and I/O interface electronics. The simulation software simulated the response of an aircraft to control surface commands and produced simulated sensor output. The actual UAV flight computer running navigation and control software connected to the simulation computer via the I/O electronics. With the completed UAV test bed, the UAV flight computer was able to fly the virtual aircraft in the simulation software thus, validating the navigation and control software. The major task of this project accomplished this year was the development of the I/O interface electronics and modifying the simulation software.

The MIT Math Model for Ship Simulation and Design and the Effects of Automation on U. S. Naval Surface Warships

Researcher: Midshipman 1/C Matthew Uebel, USN
Adviser: Associate Professor Edwin L. Zivi

As automated systems are fielded onboard U. S. Naval Surface Warships, the design and operation of future naval vessels will be dramatically altered. Manning requirements will change; command, control, computers, communications, and information systems (C4I) will be improved; and ships will become more efficient in performing their missions. Concurrently, computers play an ever increasing role in the ship design process. This research investigated the ship impact of pervasive automation using a MATLAB® version of the Massachusetts Institute of Technology (MIT) derived ship design math model to systematically predict surface ship performance with respect to a variety of design parameters and constraints. Moreover, genetic optimization was used to find Pareto optimal ship designs. The focus of this research was the qualitative and quantitative assessment of automation ship impact onboard warships.

Midshipman Design Projects

Autonomous Mobile Artillery

Researchers: Midshipmen 1/C Brett D. Abbamonte, Steven R. Iezzi and William Rietveld, USN
Adviser: Assistant Professor Joel M. Esposito

Low Cost, Fully-Autonomous, Micro Aerial Vehicle

Researchers: Midshipmen 1/C Kitan Bae and Mark T. Summerlin, USN
Adviser: Associate Professor George E. Piper

Security Robot

Researchers: Midshipmen 1/C Timothy J. Beebe, Jason E. Brownlee and George B. Watkins, USN
Adviser: Professor Kenneth A. Knowles

Windows of the Future

Researchers: Midshipmen 1/C Matthew J. Bernhardt, Trevis L. Rainey and Michael C. Sullivan, USN
Adviser: Associate Professor Edwin L. Zivi

Semi-Autonomous Remote-Controlled Watercraft
Researchers: Midshipmen 1/C Matthew J. Bettencourt and Travis S. Hail, USN
Adviser: Lieutenant Colonel Randy P. Broussard, USAF

Linear Thrust Device
Researcher: Midshipman 1/C Christopher B. Bill, USN
Adviser: Associate Professor Edwin L. Zivi

Light Tracking, Bulb Crushing Robot
Researchers: Midshipmen 1/C Kerry L. Bistline, Patrick J. Drosinos and Eric R. Zilberman, USN
Adviser: Lieutenant Colonel Randy P. Broussard, USAF

UAV
Researchers: Midshipmen 1/C Thomas R. Bock, Walter C. Driver,
Matthew J. Ostrye, Luke A. Parchment and Timothy R. Waters, USN
Adviser: Associate Professor George E. Piper

Geometrically Variable Robot
Researchers: Midshipmen 1/C Paul M. Bonarrigo, Ryan A. Munoz and Francis M. Pascucci, USN
Adviser: Associate Professor Kiriakos Kiriakidis

Vehicle Flood Alarm
Researchers: Midshipmen 1/C Jared D. Burgess and Jonathan C. Whitehurst, USN
Adviser: Professor Robert DeMoyer

Heads-Up Display (HUD) Dive Mask
Researchers: Midshipmen 1/C James J. Burns, Brian R. Demmell and Thomas E. English, USN
Adviser: Professor Carl E. Wick

The Piper Snake
Researchers: Midshipmen 1/C Adam R. Bush and Andrew E. Dumm, USN
Adviser: Professor Carl E. Wick

The Armchair Buddy
Researchers: Midshipmen 1/C Alexe Calarasu, Ryan T. Davlin, Christopher L. Glenn,
Adam M. Osborn and Richard D. Slye, USN
Adviser: Assistant Professor Matthew G. Feemster

Offshore Wind Power
Researchers: Midshipmen 1/C Parker S. Carlisle and Kathryn P. D'Epagnier, USN
Adviser: Lieutenant Commander Curtis S. Lindsay, USNR

Systems Ball
Researchers: Midshipmen 1/C Sven R. Chrisman, Jonathan B. Miller and Christopher P. Yost, USN
Adviser: Professor Terrence E. Dwan

Lap Top Control of a Commercial Off-the-Shelf Spy Helicopter
Researchers: Midshipmen 1/C William G. Cocos, Matthew J. Degree,
Jason D. Epps and Robert E. Zubeck, USN
Adviser: Professor Kenneth A. Knowles

User Interfaced Pattern Recognition Targeting System
Researchers: Midshipmen 1/C Zachary C. Conatser,
Anthony A. DiFranco and John Donnelly, USN
Adviser: Lieutenant Colonel Randy P. Broussard, USAF

USNA First Robotics Team
Researchers: Midshipmen 1/C Shane L. Ehler and Richard C. Rosenbusch, USN
Adviser: Associate Professor Bradley E. Bishop

Automatic Transmission for Bicycle
Researchers: Midshipmen 1/C Christiana M. Floeck and Timothy S. Lehman, USN
Adviser: Captain John W. Nicholson, USN

Acoustic Triangulation Defense System
Researchers: Midshipmen 1/C Michael J. Gleeson and Stan L. Lapp, USN
Adviser: Associate Professor Svetlana Avramov-Zamurovic

The Collaborative Control of Unmanned Vehicles
Researchers: Midshipmen 1/C Erik Gustafson and Christopher T. Lollini, USN
Adviser: Associate Professor Bradley E. Bishop

Water Waiter
Researchers: Midshipmen 1/C Emma A. Hagen,
Maria A. Parra-Orlandoni and Douglas R. Tomczak, USN
Adviser: Captain Owen G. Thorp III, USNR

Trinity College Firefighting Robot
Researcher: Midshipman 1/C Karl Hassenfratz, USN
Adviser: Assistant Professor Sarangi P. Parikh

Magellan Project
Researchers: Midshipmen 1/C Benjamin J. Horn, Carson C. McAbee
and Matthew J. McLaughlin, USN
Advisers: Captain Owen G. Thorp III, USNR and Associate Professor Bradley E. Bishop

Autonomous Pianist
Researcher: Midshipman 1/C Lucas R. Koran, USN
Adviser: Professor Robert DeMoyer

Automated Foosball Table
Researchers: Midshipmen 1/C Joseph A. Plot and Jesse C. Stice, USN
Adviser: Professor Thomas E. Bechert

Design of Radiological Sensor System for the Spartan Unmanned Surface Vehicle
Researcher: Midshipman 1/C Christopher J. Prescott, USN
Adviser: Associate Professor Richard T. O'Brien, Jr.

Checkers Anyone?
Researchers: Midshipmen 1/C Kristina D. Rohlin and Shaunnah Wark, USN
Advisers: Professor Thomas E. Bechert and Associate Professor Jenelle A. Piepmeier

Systems Ball
Researchers: Midshipmen 1/C Michael P. Sargent and Robert B. Shary, USN
Adviser: Professor Terrence E. Dwan

Noise Pollution
Researcher: Midshipman 1/C Peter C. Sharrai, USN
Advisers: Associate Professor Svetlana Avramov-Zamurovic
and Associate Professor George E. Piper

Ship Automation on Naval Warships
Researcher: Midshipman 1/C Matthew A. Uebel, USN
Adviser: Associate Professor Edwin L. Zivi

Builder-Bot
Researcher: Midshipman 1/C Susan L. Watters, USN
Adviser: Associate Professor Jenelle A. Piepmeier

Professional Publications

Journal (Refereed) Manuscripts

BISHOP, Bradley E., Associate Professor (co-author), "Redundant Manipulator Techniques for Partially Decentralized Path Planning and Control of a Platoon of Autonomous Vehicles," *Proceedings of the Institute for Electrical and Electronic Engineering* (*IEEE) Transactions on Systems, Man and Cybernetics Part B*, August 2005, pp. 842-849.

> An approach to real-time trajectory generation for platoons of autonomous vehicles was developed from well-known control techniques for redundant robotic manipulators. The partially decentralized structure of this approach permits each vehicle to independently compute its trajectory in real-time using only locally generated information and low-bandwidth feedback generated by a system exogenous to the platoon. Our work was motivated by applications for which communications bandwidth was severely limited, such for platoons of autonomous underwater vehicles. The communication requirements for our trajectory generation approach are independent of the number of vehicles in the platoon, enabling platoons composed of a large number of vehicles to be coordinated despite limited communication bandwidth.

KIRIAKIDIS, Kiriakos, Associate Professor (co-author), "Reconfigurable Robot Teams: Modeling and Supervisory Control," *Proceedings of the Institute of Electrical and Electronic Engineering (IEEE)Transactions on Control Systems Technology*, September 2004, Vol. 12, No. 5, pp. 763-769.

> Teams of land-based, airborne, or submerged robots constitute a new breed of robotic systems for which the issue of controlled behavior arises naturally. This work modeled the dynamics of the robot team in the discrete event system framework and design of a reconfigurable system that could handle situations in which robot units may switch offline. In particular, this work exploited the dichotomy between controllable and uncontrollable behavior to synthesize a supervisor using only controllable events, but also one whose structure adapted to uncontrollable events. The paper presented a novel method based on learning and verification for restoring supervision as well as behavioral assurance of the team.

KNOWLES, Kenneth A., Professor (co-author), "Pulse-Width Modulated Control for a Cold Water Diver Catalytic Heater Temperature Control System", *Proceedings of Underwater Intervention 2005*, February 2005. (CD-ROM)

Under the Office of Naval Research funding, a laboratory prototype heating system for closed-circuit hot water suits using hydrogen catalytic reactions in a semi-closed circuit was designed, fabricated, and tested in the Hydrospace Laboratory at the Coastal Systems Station in Panama City, FL. Unmanned and manned testing and evaluation verified that satisfactory performance of the heater can be achieved for two to six divers operating in a 0°C (32°F) environment, but undesirable time lags in correcting temperature were experienced for varying heat loads as the number of connected divers was varied. An improved microprocessor heater control system has since been developed and tested using several small prototype systems. This proof of concept heater controller was designed to verify the use of a small microprocessor circuit with pulse-width modulated (PWM) control valves in controlling the heater and suit water temperatures. The PWM valves greatly simplified the control hardware. In the process of developing this controller, it was discovered that a hot water mixing strategy could eliminate the undesirable temperature control time lags experienced in the original system. This paper described the theory, development, and operation of this system with its improved heater control strategy.

PARIKH, Sarangi P., Assistant Professor (co-author), "Usability Study of a Control Framework for an Intelligent Wheelchair," *Institute of Electrical and Electronic Engineering (IEEE) International Conference on Robotics and Automation (ICRA) 2005*, April 2005. (CD-ROM)

This paper described the development and assessment of a computer-controlled wheelchair equipped with a suite of sensors and a novel interface, called the SmartChair. A shared control framework with different levels of autonomy allowed the human operator to stay in complete control of the chair at each level while ensuring their safety. The framework incorporated deliberative motion plans or controllers, reactive behaviors, and human user inputs. At every instant in time, control inputs from these three different sources were blended continuously to provide a safe trajectory to the destination, while allowing the human to maintain control and safely override the autonomous behavior. This paper presented usability experiments with 50 participants and demonstrated quantitatively the benefits of human-robot augmentation.

PARIKH, Sarangi P., Assistant Professor (co-author), "Hybrid Deliberative/Reactive Control Framework for Human-Robot Interaction," *18th International Congress of Mechanical Engineering (COBEM 2005),* May 2005. (CD-ROM)

This paper presented a control framework that combines a deliberative motion plan, local reactive behaviors and human-initiated inputs. The deliberative motion plan was described by an approximated navigational function created over a map of the environment. This function had a unique global minimum at a desired goal destination, and by using this function the robot navigated autonomously to the goal. While navigating, the robot sensed the world and detected unpredicted obstacles along the way, and by using local reactive behaviors, the robot avoided obstacles without disregarding the motion plan. At any point, the user could give inputs to the system that were incorporated into the system. These three distinct and at times conflicting control inputs were combined in a proper way. Some experimental results were shown in a not simply connected environment using our robot that had a suite of sensors including sonar, infrared sensors, and an omni-directional camera. In these experiments the user used a joystick connected to a network computer to provide inputs to the system. This paper demonstrated that the robot is able to replan when necessary or warn the user if it is impossible to get to the goal.

PIPER, George E., Associate Professor (co-author), "Design and Development of the Samara Stop-Rotor Hybrid Micro Air Vehicle," *Proceedings of the 20th Bristol International Conference on UAVs,*" Bristol, UK, April 2005. (CD-ROM)

The Samara micro air vehicle (MAV) was a stop-rotor hybrid aircraft capable of both rotary and fixed wing flight. It employed a pair of single-blade, rotary/fixed wing panels that were attached at their roots to separate coaxial shafts. For low-speed flight the wing panels were driven as contra-rotating rotor blades for lift, while a conventional propeller provided forward thrust. The rotor system was longitudinally unbalanced, causing a fore-and-aft vibration, but at the small scale of the vehicle (under 500 grams) this vibration was tolerable. In fixed wing flight the wing panels were stopped opposite each other to become a conventional wing. This configuration eliminated the airflow reversal over the wing that occurred upon conversion in other stop-rotor designs.

For initial testing, the Samara was configured with the wing/rotor panels mounted forward, a conventional airplane empennage, and a pusher propeller, so that in fixed wing mode the vehicle assumed a conventional airplane shape. Flight control of this configuration (now designated Samara 1) was marginal in rotary wing flight. A revised configuration, Samara 2, now in development, will have a canard configuration in fixed wing flight. The canard surface, equipped with twin, contra-rotating tractor propellers, will act as a tilt wing. In rotary wing flight the main wing/rotor will provide lift, while the upward-tilted propellers give control and additional lift. Differential propeller thrust will give roll control, collective thrust will provide pitch control, and differential tilt of the propellers will give yaw control. Advantages of the new configuration over Samara 1 are: control of rotor flapback by varying the vertical thrust contribution of the tilt propellers and canard with airspeed; improved pitch, yaw, and roll control for zero/low airspeed rotary-wing flight; and the aircraft's center of gravity will be better positioned for both rotary wing and fixed wing modes.

Conference Proceedings

AVRAMOV-ZAMUROVIC Svetlana, Associate Professor, and PIPER, George E., Associate Professor (co-authors), "Standard Capacitor Calibration Procedure Implemented Using Control Software," *Proceedings of the American Society for Engineering Education (ASEE)*, Salt Lake City, UT, June 2005. (CD-ROM)

A capacitance scaling method was used to calibrate standard capacitors. This was a very powerful technique that was introduced by Aoki and Yokoi in 1997 [1]. Reference [1] describes the general method and provides a detailed uncertainty analysis. Aoki and Yokoi developed a calibration procedure based on [1] but this reference was insufficient for duplication of the measurement system and implementation of the calibration procedure.

The capacitance scaling procedure involved reference point measurements and a series of "scaling" measurements. A commercial capacitance bridge was used in order to obtain reference measurements at 1 kHz. An inductive voltage divider (IVD) with the ratio of 10:1 was used to scale a known capacitance for comparison with a capacitance under test. The measurements were performed over a range of frequencies. This paper presented the capacitance scaling procedure in detail and demonstrated the developed software program that controls the calibration procedure. The challenge of this presentation was to explain a rather sophisticated precision measurement technique in such a way that it may be taught to an interested group of undergraduate students. The software development provided an opportunity to teach the calibration process: from taking measurements to producing a calibration report.

AVRAMOV-ZAMUROVIC, Svetlana, Associate Professor (co-author), "Inductance Measurement Using an LCR Meter and a Current Transformer Interface," *Proceedings of the 2005 Instrumentation and Measurement Technology (IMTC) Conference*, Ottawa, Canada, May 2005. (CD-ROM)

Traditional calibration support for commercially available four-terminal-pair (4TP) LCR meters involved the use of capacitance, resistance, and inductance standards with known frequency characteristics. This paper described a new inductance measurement system where an unknown inductance standard was compared to known capacitance and resistance standards using a commercially available LCR meter, a commercially available audio frequency capacitance bridge, and a multi-stage, programmable-ratio, current transformer. The described measurement system was relatively simple, used mainly commercially available instrumentation, and achieved acceptable inductance measurement uncertainty over the 50 Hz to 20 kHz frequency range.

It was established that commercially available LCR meters have relatively good linearity characteristics over narrow measurement ranges [1], making them well suited as transfer devices when comparing impedances of nominally equal values. In recent years, highly accurate, three-terminal (3T) capacitance bridges operating over the 50 Hz to 20 kHz frequency range have become commercially available with measurement uncertainties approaching metrological levels [2]. In addition, multi-stage, amplifier-aided current transformers have been routinely developed that achieve errors below a few parts in 10^6 over the 50 Hz to 20 kHz frequency range [3-4]. In order to improve and simplify the present inductance measurement services at NIST, an attempt has been made to exploit these three technologies by developing a system to compare an inductance standard under test to a capacitance standard having an equivalent impedance magnitude at the frequency of interest. The GR1482 inductance standards traditionally used for the dissemination of the Henry typically have large series resistance components, so equivalent impedances must be synthesized using parallel combinations of capacitance and resistance standards.

AVRAMOV-ZAMUROVIC, Svetlana, Associate Professor, and PIPER, George E., Associate Professor (co-authors), "Measuring Voltage Balance Using a Switching Scheme," *Proceedings of the American Society for Engineering Education (ASEE)*, Portland, OR, June 2005. (CD-ROM)

Most precise electrical impedance measurement procedures involve an ac voltage balance. A voltage balance was defined as the condition in which the difference between two voltages was driven to zero by independent voltage injections. The uncertainty of the measured value directly depends on how close to zero the balance was driven in magnitude and phase. The uncertainty level required by current state-of-the art impedance experiments was on the order of 1×10^{-6} (one part per million). Traditionally, voltage balance was achieved using inductive voltage dividers in a bridge configuration. Inductive voltage dividers were used because they can provide acceptable uncertainties. This paper explored the possibility of using electronics instead of inductive voltage dividers in a generalized bridge configuration.

This paper described in detail a measurement system that required a precise voltage balance. The measurements involve a switching scheme that helps to eliminate voltage offsets and that aids the iterative process of driving the voltage difference to zero. The mathematical model of the system was described and the balance voltage derived. The validity of the assumptions were checked by using software simulation. This was preliminary work that required experimental confirmation. Based on the results of the proposed algorithm an experiment may be planned in which the system will be constructed and the suggested measurement procedure tested.

In the Systems Engineering Department at the U.S. Naval Academy, we strongly emphasize the highest level of design projects. The proposed research presented a very good opportunity to teach students the full design cycle. This experiment was well defined using mathematical tools and in that sense it is a straightforward task to develop a software simulation. The actual construction of the measurement system was rather complex, but students will benefit from using it once it has been completed. Making measurements to verify the model increased our understanding of the developed system.

BISHOP, Bradley E., Associate Professor, "Control of Platoons of Non-holonomic Vehicles Using Redundant Manipulator Analogs," *Proceedings of the Institute for Electrical and Electronic Engineering* (*IEEE) International Conference on Robotics and Automation,* April 2005, pp. 4617– 4622.

This work considered methods for control of platoons of cooperating non-holonomic vehicles using techniques based on redundant manipulator control. The class of tricycle-like robots was chosen, as it possesses significant limitations and represents a vast class of real vehicles with application beyond the basic differential drive. The method presented accounts for limitations on both steering and speed. The efficacy of the technique was shown through simulation studies.

BISHOP, Bradley E., Associate Professor (co-author), "Combining Classical and Behavior-Based Control for Swarms of Cooperating Robots," *Proceedings of the Institute for Electrical and Electronic Engineering* (*IEEE) International Conference on Robotics and Automation,* April 2005, pp. 2510 - 2515.

This paper related a hybridization of classical control and behavior-based methods for control of cooperating autonomous vehicles performing a search mission. The controller developed inherits the best characteristics of each of the approaches with few of the drawbacks. Simulation studies show the efficacy of the control for a simple mission.

BISHOP, Bradley E., Associate Professor, "Teaching Robot Design: Locomotion Beyond Differential Drive," *Proceedings of the 2005 American Society for Engineering Education (ASEE) Conference and Exposition*, Portland, OR, June 2005. (CD-ROM)

This paper presented a novel design challenge for a mobile robotics course, focusing on locomotive methodologies and mechanism design. This exercise required that the students design a robot for locomotion over complex and challenging terrain. This exercise demonstrated the difficulties associated with non-trivial terrain and provided the students with an excellent experiential learning opportunity that significantly enhanced their robot deign capabilities by expanding their experience beyond simple differential drive systems.

BISHOP, Bradley E., Associate Professor and WICK, Carl E., Professor, "Analog Computation for Mobile Robotics Education," *Proceedings of the 2005 American Society for Engineering Education (ASEE) Conference and Exposition*, Portland, OR, June 2005. (CD-ROM)

This paper presented a mobile robot design exercise that relied on simple analog circuits to accomplish tasks that were typically carried out using microcontrollers. Students were challenged to use simple analog sensors and IC's to develop a mobile robot that was attracted to a light source while avoiding obstacles. The primary outcome of this exercise was a deeper understanding of computation for mobile robots, and a clearer view of possible alternatives to embedded processors for low-cost applications.

BISHOP, Bradley E., Associate Professor (co-author), "On Wave Prediction for Ship Roll Stabilization," *Proceedings of the 37th Institute for Electrical and Electronic Engineering (IEEE) Southeastern Symposium on Systems Theory,* March 2005, pp. 25 – 29.

This paper focused on the evaluation of the use of wave prediction for roll stabilization in surface vessels. Using a simple ARX wave prediction method, various disturbances and sensing errors were evaluated for effect on roll stabilization using an ideal roll control system. The result of the simulation studies was a set of bounds on predictor performance for this 'best case' control scheme, providing insight into sensor system design and wave prediction schemes for roll stabilization.

BISHOP, Bradley E., Associate Professor, "Design and Control of Platoons of Cooperating Autonomous Surface Vessels," *Online Proceedings of the 7th Maritime Transportation System Research and Technology Coordination Conference,* November 2004. (http://www.trb.org/Conferences/MTS/Program.asp), http://www.trb.org/Conferences /MTS/1A%20Bishop%20Paper.pdf).

This work focused on the development of a provable, reliable and efficient strategy for coordination of groups, or platoons, of small, autonomous surface vessels for use in maritime security operations. This work was built on successful techniques that have been developed for coordination of platoons of holonomic vehicles as well as technology that was utilized in the development of an autonomous surface vessel test bed.

BROUSSARD, Randy P., Lieutenant Colonel, USAF and PIEPMEIER, Jenelle A., Associate Professor, "The Use of MATLAB for Robotic Control in an Undergraduate Robotics Laboratory," *Proceedings of the American Society for Engineering Education* (*ASEE) Annual Conference and Exposition,* Salt Lake City, UT, June 2004.

This article discussed a computer vision curriculum, including laboratory exercises, which were suitable for undergraduate engineering students. While classroom and laboratory exercises focused on off-line computation, on-line implementation can be achieved with simple equipment such as web-cams. Exercises included a sidewalk or line following exercise utilizing the Hough transform, a face recognition using eigenfaces, barcode reading, handwriting recognition, and sign language recognition. Data-set development for these exercises was also discussed. MATLAB® and the Image Processing Toolbox were utilized to allow students to focus on higher-level understanding of commonly available image processing tools. The use of advanced tools allowed students to attempt and finish meaningful examples. This paper focused on exercises that serve as a useful complement to robotics curriculum and student robotics projects.

ESPOSITO, Joel M., Assistant Professor, "Artificial Potential Field Controllers for Robust Communication in a Network of Swarm Robots", *Proceedings of the Institute for Electrical and Electronic Engineering (IEEE) Southeastern Symposium on Systems Theory*, Tuskegee, AL, March 2005, pp. 401-405.

An active area of research in the robotics community is "swarm control," where many simple robots work together to execute tasks which are beyond the capability of any single robot acting alone. Yet in order for the swarm members to work together effectively they must maintain a reliable and robust wireless communication network among them. The goal of this project was to investigate motion control laws which fulfill the dual and sometimes conflicting requirements of executing a primary mission (e.g. search and rescue) while maintaining a robust mobile wireless communication network among the swarm members. Three different spatial requirements for robust communication were considered in this project: proximity, line of sight and redundancy. To this end, several artificial potential fields were developed and simulated to determine their success in controlling the swarm. The strengths and weaknesses, the design process and the interaction of the controllers constitute the heart of the paper. At a higher level, the challenge of how to compose these motion control laws to achieve the primary mission in a meaningful way was addressed.

ESPOSITO, Joel M., Assistant Professor, AVRAMOV-ZAMUROVIC, Svetlana, Associate Professor, DEMOYER, Robert., Professor and PARIKH, Sarangi P., Assistant Professor, "Promoting and Assessing Intuitive Understanding in a Junior-Level Modeling Course," *Proceedings of the American Society for Engineering Education (ASEE),* Portland, OR, June 2005. (CD-ROM)

Many faculty have observed that even the best engineering students have difficulty taking a complicated real-life device and developing a tractable mathematical model of its operation for the purposes of simulation or control design. The major obstacles to this desired outcome stems from three deficiencies. (1) Difficulty in using appropriate simplifying assumptions to render a tractable mathematical model of a complex device. (2) A lack of experience in designing experiments to measure physical parameters of a device and a lack of intuitive understanding of the appropriate ranges of these parameters. (3) Failure to

use electronic resources such as databases and internet to discover how more complicated devices, not discussed in lecture, operate.

In fact these issues were explicitly addressed in ABET's Criteria for Accrediting Engineering Programs. While traditional textbook and exam problems do a fine job conveying the procedural and mathematical concepts of modeling physical systems, it is much more difficult to give students an understanding of the artful aspects of the modeling process outlined above. This paper described a series of laboratory and homework exercises designed to help students hone these skills, discuss how to assess their performance on the exercises and share the results of student opinion surveys.

ESPOSITO, Joel M, Assistant Professor (co-author), "Randomized Test Case Generation for Hybrid Systems: Adaptive Sample Biasing," *Proceedings of the Institute for Electrical and Electronic Engineering (IEEE) Co-sponsored American Control Conference*, Portland, OR, June 2005, pp. 1166-1172.

A randomized approach to test generation for hybrid systems was developed, and control systems in general, inspired by the Rapidly-exploring Random Trees (RRTs) technique from robotic path planning. This technique proved successful in solving high dimensional nonlinear problems. The approach represented an automated analysis alternative for systems where computing the reachability set was intractable. The standard RRTs method created a tree in the state space by uniformly generating a random sampling point and trying to find inputs which connected them. In this paper a novel adaptive sampling strategy was proposed. This technique initially biased the distribution so that states near the "unsafe" set were selected. The growth of the tree was continually monitored. As the growth rate of the tree declined the sampling distribution was adjusted to be less biased. This adaptive search strategy varied bias between "greedy" and global, often finding test trajectories more quickly than the traditional algorithm.

FEEMSTER, Matthew G., Assistant Professor, (co-author), "Tracking Control of an Underactuated Unmanned Underwater Vehicle," *Proceedings of the American Controls Conference*, Portland, OR, June 2005, pp. 4321-4326.

In this paper, a robust position tracking controller was developed for an autonomous, underactuated, unmanned underwater vehicle (UUV). Specifically, the proposed controller forces the three dimensional (*i.e.*, longitudinal, latitudinal, and depth) position tracking error to within an arbitrarily small region about zero (i.e., global exponential uniformly ultimately bounded tracking) through the utilization of one translational and three orientation actuators. Therefore, the proposed methodology may hold special appeal to such underactuated applications as the omni-directional intelligent navigators (ODINs) by extending capabilities to include changes in vehicle depth. In addition, uncertainty in such parameters as vehicle inertia and hydrodynamic damping forces were compensated through a robust control structure. Simulation results were provided to illustrate performance and details of the controller.

FEEMSTER, Matthew G., Assistant Professor, "Utilization of a Dynamometer/MATLAB Environment within a Linear Controls Design Project," *Proceedings of the American Society for Engineering Education (ASEE)*, Portland, OR, June 2005. (CD-ROM)

In this paper, a dynamometer setup was coupled with a MATLAB hardware interface to offer an experimental test stand from which students can observe the effects of loading in an electric motor application. The dynamometer system was utilized within a linear systems design project in which the students were required to design a speed tracking compensator while simultaneously ensuring that current limitations for the selected drive electronics were not exceeded.

GUSTAFSON, Erik H., Midshipman 1/C, USN, LOLLINI, Christopher T., Midshipman 1/C, USN, BISHOP, Bradley E., Associate Professor and WICK, Carl E., Professor, "Swarm Technology for Search and Rescue Through Multi-Sensor Multi-Viewpoint Target Identification, *Proceedings of Southeastern Symposium on Systems Theory (SSST)*, Tuskegee, AL, March 2005. (CD-ROM)

This paper documented independent student research projects that involved novel design approaches to navigation and communication between robots over rough terrain, as may be found in search and rescue situations.

KIRIAKIDIS, Kiriakos, Associate Professor and O'BRIEN, Jr., Richard T., Associate Professor, "H-Infinity Based Identification of Stiffness in the Presence of Uncertainty," *Proceedings of the American Society for Mechanical Engineers (ASME) International Mechanical Engineering Congress and Exposition*, Anaheim, CA, November 2004. (CD-ROM)

The authors proposed the identification of stiffness using the H-Infinity performance criterion and a nominal state-space model of the flexible system. The parameter estimator took the form of an extended H-infinity filter, which was robust to uncertainties such as modeling error.

KIRIAKIDIS, Kiriakos, Associate Professor and O'BRIEN, Jr., Richard T., Associate Professor, "H-Infinity Filtering Parameter Estimation for State-Space Systems," *Proceedings of the American Control Conference*, Boston, MA, June 2004, pp. 2836-2839.

This paper investigated the nonlinear problem of parameter identification for systems with time-varying state-space models using the idea of an extended filter. To treat uncertainty in the data or the model, the paper followed the approach of H-infinity filtering. It showed that the parameter estimation error satisfied exactly albeit locally the prescribed gain criterion as long as the extended filter meets a modified---tighter---criterion. In the infinite horizon case, the paper also showed that the modified H-infinity criterion leads to an asymptotically stable state estimation error without assuming zero-state observability of the associated error equation.

O'BRIEN Jr., Richard T., Associate Professor, PIEPMEIER, Jenelle A., Associate Professor, HOBLET, Philip C., Midshipman (Trident Scholar 2003), BURNS, Steven R., Midshipman (Trident Scholar 2002), and GEORGE, Charles E., Midshipman (Class of 2004), "Scale-Model Vehicle Analysis Using an Off-the-Shelf Scale Model Testing Apparatus," *Proceedings of the American Control Conference*, Boston, MA, July 2004, pp. 3387-3392.

A standard exercise treadmill was used to create a scale-model vehicle simulator. The motion of the treadmill beneath the scale-model vehicle simulated the motion of a full-size vehicle on a paved road. The Scale-Model Testing Apparatus incorporated off-the-shelf components and commercially available, scale-model vehicles which facilitated the development of the apparatus in an undergraduate setting. An overhead vision system provided a tether-free assessment of the vehicle's position and orientation. Dynamic similitude between the scale-model vehicle and an "average" full-size vehicle was achieved through a series of straightforward modifications to the scale-model vehicle. Preliminary results of longitudinal and lateral control designs were presented.

O'BRIEN Jr., Richard T., Associate Professor, and KIRIAKIDIS, Kiriakos, Associate Professor, "Reduced-Order H-Infinity Filtering for Discrete-Time, Linear, Time-Varying Systems," *Proceedings of the American Control Conference*, Boston, MA, July 2004, pp. 4120-4125.

The reduced-order, H-infinity filtering problem for discrete-time, linear, time-varying systems were considered. A solution was obtained by converting the reduced-order, filtering problem into a full-order, filtering problem with the same dimension as the reduced-order filter. The resulting filter was unbiased and had a unique realization for each set of design parameters. Furthermore, it was shown that the previously

proposed solution was independent of the H-infinity design parameters and, therefore, did not represent a solution to the problem.

O'BRIEN Jr., Richard T., Associate Professor, and WATKINS, John M., Associate Professor, "A Unified Procedure for Discrete-Time Root Locus and Bode Design," *Proceedings of the American Control Conference*, Portland, OR, June 2005. (CD-ROM)

As an alternative to the numerous distinct controller design algorithms in discrete-time textbooks, a simple, unified design approach was presented for all standard discrete-time, classical compensators independent of the form of the system information. This approach was based on a simple root locus design procedure for a proportional-derivative (PD) compensator. From this procedure, design procedures for discrete-time lead, proportional-integral (PI), lag, proportional-integral-derivative (PID), and PI-lead compensators were developed. With this proposed approach, students can concentrate on the larger control system design issues, such as compensator selection and closed-loop performance, rather than the intricacies of a particular design procedure. To demonstrate this approach, an example of a lead design from a digital control system laboratory was presented.

PIEPMEIER, Jenelle A., Associate Professor ,and WATERS, Jennifer K., Associate Professor (Naval Architecture and Ocean Engineering Department), **"**Analysis of Stereo Vision-based Measurements of Laboratory Water Waves," *Proceedings of the Institute for Electrical and Electronic Engineering (IEEE) International Geo-science and Remote Sensing Symposium,* Anchorage, AK, September 2004, pp. 3592 – 3595.

Pro-active ride control systems have the potential to improve seakeeping effects for high-speed vessels. By enabling the vessel to adjust for waves it has not yet encountered, the vessel's seakeeping characteristics may be significantly improved, allowing it to reach higher speeds. This paper investigated the feasibility of a vision-based wave sensing approach that would be able to determine pertinent wave characteristics, such as slope, height, and frequency. A stereo vision-based system was successfully applied to the in-situ measurement of laboratory water waves. Surface plots of the initial results from imaging regular sinusoidal waves at the Davidson Lab at Stevens Institute of Technology indicate excellent horizontal and vertical correlation with the generated wave characteristics. Validation of this data was obtained by conventional wave probes mounted at two different locations in the tank.

WATERS, Jennifer K., Associate Professor (Naval Architecture and Ocean Engineering Department), PIEPMEIER, Jenelle A., Associate Professor, and GROB, Jennifer, Ensign, USN, "Stereo Vision-Based Measurement of Laboratory Water Waves," *Proceedings of the 27th American Towing Tank Conference (ATTC)*, St. Johns, Newfoundland, August 2004. (CD-ROM)

A stereo vision-based system was successfully applied to the in-situ measurement of laboratory water waves. The system equipment included a stereo vision camera system from Point Grey Research, which was capable of producing surface data in the form of point cloud images. MATLAB was used to analyze the recorded data and compute critical information, such as local maxima and minima, for examining basic wave characteristics. A sample surface plot of initial results from the imaging of regular sinusoidal waves in Tank 3 of the Davidson Lab at Stevens Institute of Technology was shown in Figure 1. The initial wave image results indicated excellent horizontal and vertical correlation with the generated wave characteristics. Validation of this data was obtained from measurements by conventional wave probes mounted at two different longitudinal locations in the tank.

ZIVI, Edwin L., Associate Professor (co-author), "An Optimization Approach to Estimating Stability Regions Using Genetic Algorithms," *Proceedings of the 2005 American Automatic Control Conference (AACC)*, Portland, OR, June 2005. (CD-ROM)

The problem of estimating regions of asymptotic stability for nonlinear dynamic systems was considered as an optimization problem. Genetic algorithms were then proposed to solve the resulting optimization problems. Three test systems were then used to evaluate the performance of the proposed genetic algorithms. The test systems are 6th, 8th, and 17th order highly nonlinear power electronics systems. The performance of the genetic algorithms was also compared with that of the classical Broyden-Fletcher-Goldfarb-Shanno (BFGS) algorithm and the simplex method of Nelder and Mead. Time domain simulations of the test systems were performed to validate the results of the optimization algorithms. Issues involved with the successful implementation of genetic algorithms to estimate regions of attraction were discussed. It was observed that genetic algorithms outperform the classical optimization algorithms in estimating regions of asymptotic stability.

ZIVI, Edwin L., Associate Professor (co-author), "Improvement of Fault Tolerance in AC Motor Drives Using A Digital Delta-Hysteresis Modulation Scheme," *Proceedings of the Power Electronics Specialist Conference*, Aachen, Germany, June 2005. (CD-ROM)

In this paper, a novel digital delta-hysteresis regulation (DDHR) scheme was proposed that allows motor drive systems to maintain relatively accurate control of phase currents in the event of the loss of all phase current sensors. Within the scheme, line currents were reconstructed using knowledge of the DC-link current and switching states. The generation of switching signals was based upon traditional delta-hysteresis regulation (DHR). However, modifications were made to DHR to ensure the DC-link current always contained sufficient information to reconstruct phase currents. Experimental results obtained from a vector-controlled induction machine were used to show that there is a relatively small difference between the performance of the pre- and post- fault systems.

ZIVI, Edwin L., Associate Professor, "Design of Robust Shipboard Power Automation Systems," *Proceedings of the International Federation of Automatic Control (IFAC) Control Applications in Marine Systems Conference (CAMS 2004)*, Ancona, Italy, July 2004. (CD-ROM) (Invited Plenary Lecture)

Emergent power and automation technologies provide new opportunities and challenges for multidisciplinary ship design. In particular, these dynamically interdependent systems require dependable, fault tolerant control to efficiently manage limited resources and to respond to casualty conditions. Design of an electric warship engineering and damage control system of systems was considered as an illustrative example. In this context, cost and survivability were considered as either deterministic or probabilistic independent variables. In the stochastic formulation, design robustness was defined with respect to uncertainties including technology readiness, mission creep and operational environment.

ZIVI, Edwin L., Associate Professor, "Engineering Casualty Control Automation," *Proceedings of the American Society for Mechanical Engineers (ASME)Reconfiguration and Survivability Symposium (RS 2005)*, Atlantic Beach, Florida, February 2005. (CD-ROM) (Invited Plenary Lecture)

A new formulation and methodology for the assessment and design of an automated Integrated Engineering Plant (IEP) was proposed. This formulation emphasized time domain continuity of vital engineering services despite the spatial and temporal bursts of disruption which typify weapons effects. The overall objective was a set of design tools which allowed the systematic exploration of new automation, engineering plant and damage control architectures, topologies and technologies. Toward this objective, several design innovations were proposed: (1) methods allowing damage tolerance to be specified as an independent design parameter; (2) the use of genetic algorithms to systematically generate design alternatives; (3) the use of genetic algorithms to systematically evaluate the candidate system damage

tolerance with respect to a population of likely threats and; (4) a stochastic formulation wherein the design maturity can be deduced from the resulting probability density.

This investigation considered the dynamic interdependence of vital engineering services including mobility, power and thermal management to address the vulnerability and recoverability of an automated Integrated Engineering Plant. In particular, the operability or weighted sum of the continuity or quality of service delivery to vital loads for a specific design subjected to a specific damage scenario was mathematically defined. Moreover, using a probabilistic damage characterization, the dependability of system design alternatives were numerically determined with respect to a fixed but arbitrary set of likely damaged scenarios. Ongoing efforts include: (1) derivation of succinct, dynamically interdependent Integrated Engineering Plant models; (2) formulation of specific design metrics; (3) use of genetic algorithms for nested design and damage tolerance calculations; and (4) the use of arrays of processors handle the computational burden.

Book Chapter

ESPOSITO, Joel M., Assistant Professor (co-author), "Adaptive RRT's for Validating Hybrid Robotic Control Systems," *Springer Lecture Notes in Computer Science Series: Sixth International Workshop on the Algorithmic Foundations of Robotics,* Springer Berlin Heidelberg, New York, (2005), pp. 107-121 .

Most robot control and planning algorithms are complex, involving a combination of reactive controllers, behavior-based controllers, and deliberative controllers. The switching between different behaviors or controllers makes such systems hybrid, *i.e.* combining discrete and continuous dynamics. While proofs of convergence, robustness and stability are often available for simple controllers under a carefully crafted set of operating conditions, there is no systematic approach to experimenting with, testing, and validating the performance of complex hybrid control systems. This paper addressed the problem of generating sets of conditions (inputs, disturbances, and parameters) that might be used to "test" a given hybrid system. The method of Rapidly exploring Random Trees (RRTs) was used to obtain test inputs. The traditional RRT was extended, which only searches over continuous inputs, to a new algorithm, called the Rapidly exploring Random Forest of Trees (RRFT), which can also search over time invariant parameters by growing a set of trees for each parameter value choice. We introduced new measures for coverage and tree growth that allows us to dynamically allocate our resources among the set of trees and to plant new trees when the growth rate of existing ones slows to an unacceptable level. The application of RRFT to testing and validation of aerial robotic control systems was demonstrated.

ESPOSITO, Joel M., Assistant Professor (co-author), "An RRT-Based Algorithm for Testing and Validating Multi-Robot Controllers," *Robotics: Science and Systems,* MIT Press, (2005), pp. 21-33.

The problem of testing complex reactive control systems and validating the effectiveness of multi-agent controllers was addressed. Testing and validation involved searching for conditions that lead to system failure by exploring all adversarial inputs and disturbances for errant trajectories. This problem of testing was related to motion planning, with two main differences. Unlike motion planning problems, systems are typically not controllable with respect to disturbances or adversarial inputs and the reachable set of states was a small subset of the entire state space. In both cases, however, there was a goal or specification set consisting of a set of points in state space that was of interest, either for demonstrating failure or for validation. This paper considered the application of the Rapidly Exploring Random Tree algorithm to the testing and validation problem. Because of the differences between testing and motion planning, three modifications to the original RRT algorithm were proposed. First, because the reachable state space was generally a small fraction of the total state space, the node selection strategy was modified appropriately. Second, a new metric was developed which encoded local information about the system's dynamics. Finally, a scheme was proposed for adaptively modifying the sampling probability distribution based on measures of coverage and proximity to the specification set. the application of the algorithm was demonstrated via three simple and one large scale example and provided computational statistics. Our

algorithms were applicable beyond the testing problem to motion planning for systems that were not small time locally controllable.

ZIVI, Edwin L., Associate Professor (co-author), "Control, Optimization, Security, and Self-Healing of Benchmark Power Systems," *Adaptive Dynamic Programming*, Wiley-Interscience, (2004), pp. 599-633.

This chapter presented several challenging and benchmark problems from the field of power systems. The first benchmark was the IEEE 118 Bus commercial terrestrial Electrical Power System (EPS). The second benchmark represented a finite inertia hybrid ac/dc shipboard Integrated Power System (IPS). The analytic utility and Navy benchmark models and their respective simulations have been experimentally validated and have been used to determine system reliability, re-configurability, stability, and security. The challenge was to provide novel control and optimization methods and tools to improve the quality of service despite natural and hostile disruptions under uncertain operating conditions. Along with these problems several smaller problems were also presented which demonstrated different aspects of the challenges of power system control. The purpose of this chapter was a formulation of problems that ADP methods could be applied to, therefore the emphasis was more on detailed problem description and simulation, not on any particular solution.

Technical Reports

O'BRIEN, Jr., Richard T., Associate Professor and KIRIAKIDIS, Kiriakos, Associate Professor, "An H-Infinity-Based Detection and Tracking Method for Underwater Sensor Systems," Office of Naval Research (ONR) Year End Report, September 2004.

The long-term goal for this project was to develop a robust algorithm for the detection and tracking of moving targets in the near field using a single snapshot of measurements from an array of sensors with arbitrary geometry. There were three goals for the algorithm development. First, the algorithm was adaptable to different sensors, array geometries, and sources (narrow-band and broad-band). Second, the algorithm maintained an acceptable performance level in the presence of unmodeled phenomena (e.g., scattering at the source) and measurement noise. Third, the algorithm was computationally efficient and amenable to local processing at each sensor. The objectives of the project were the following: 1) to generalize the H-infinity based Direction-Of-Arrival (DOA) estimator, currently developed for sources in the far field and a Uniformly-spaced Linear Array (ULA), in order to estimate the azimuth, elevation, and range, 2) developed an appropriate form of the array model so that the characteristics of a near-field source were identifiable from measurements collected by an array of arbitrary geometry, 3) assessed the efficiency - analogously to the Cramer-Rao bound - of the H-infinity based DOA estimator, and 4) developed a single-snapshot source detection scheme in the H-infinity setting.

ZIVI, Edwin L., Associate Professor, CIEZKI, John G., Associate Professor (Electrical Engineering Department), Zhu1, W., Pekarek, S., Fahimi, B., "Automatic Sensor Fault Diagnosis and Controller Reconfiguration for Induction Motor Drive Sensor Fault Tolerance," Electric Ship Integration Task 1.2.9 Year 2 Report, December 2004.

Vector controlled induction motor (IM) drives traditionally use a position sensor, phase current sensors, a dc-link voltage sensor, and a dc-link current sensor. In this research, a sensor fault-diagnosis and fault-tolerance scheme for IM drives was presented that allows an IM drive system to operate properly in the event of sensor failures. The scheme automatically detected the events of sensor faults or sensor recovery and reconfigures the controller to yield the best performance out of the remaining sensors. This report documented the multiple steps that have been used to reach the automatic sensing/reconfiguration capability. Specifically, a novel current regulation method, Digital Delta-Hysteresis Regulation (DDHR) scheme was first presented wherein all the phase currents were accurately reconstructed and controlled using only the dc-link current sensor. Thus, phase current sensors fault-tolerance was accomplished first. A model-based adaptive reconstruction algorithm (MRAS) position sensorless control was then adopted to

provide position sensor fault-tolerance. Finally, a combination of DDHR and MRAS was established to maintain vector control despite the loss of all the phase current sensors position sensors. Simulation and experimental results were provided to show the effectiveness of the proposed scheme.

Other

PARIKH, Sarangi, P., Assistant Professor, "A Framework for Shared Motion Control: Human-Robot Augmentation with Applications to Assistive Technology," University of Pennsylvania, PhD Thesis in Mechanical Engineering and Applied Mechanics, March 2005.

In this thesis, a solution to the motion planning and control problem that combines three different, and at times conflicting, control inputs: deliberative plans, local reactive behaviors, and unpredictable user-initiated goals was presented. The results systematically brought together these different inputs and developed a hierarchical shared motion control framework. This framework could be used for semi-autonomous robotic systems. Our experimental platform was a robotic wheelchair where the user and robot share control of the motion. Controllers at each level were derived and implemented. For example, the SmartChair was driven to a user-specified location on an omni-directional camera image. After developing basic navigation abilities, these modular behaviors were composed together to perform more complex tasks, which required multiple controllers. At an even higher level of the hierarchy, the system chose appropriate behaviors to drive to a user-specified location. In the completed semi-autonomous system, users were able to interact with the autonomous system at any given time during the execution of a task.

Presentations at Professional Meetings and Conferences

AVRAMOV-ZAMUROVIC, Svetlana, Associate Professor, Waltrip, Brian, Koffman, Andrew and PIPER, George E., Associate Professor, "Measuring Voltage Balance Using a Switching Scheme," American Society for Engineering Education (ASEE) Conference, Portland, OR, June 2005.

AVRAMOV-ZAMUROVIC, Svetlana, Associate Professor, Waltrip, Brian, Koffman, Andrew and PIPER, George E., Associate Professor, "Standard Capacitor Calibration Procedure Implemented Using Control Software," American Society for Engineering Education (ASEE) Conference, Salt Lake City, UT, June 2005.

AVRAMOV-ZAMUROVIC, Svetlana, Associate Professor, Waltrip, Brian, and Koffman, Andrew, "Inductance Measurement Using an LCR Meter and a Current Transformer Interface," Instrumentation and Measurement Technology (IMTC) Conference, Ottawa, Canada, May 2005.

Benstead, Neil W. J. and BISHOP, Bradley E., Associate Professor, "On Wave Prediction for Ship Roll Stabilization," Institute for Electrical and Electronics Engineering (IEEE) Southeastern Symposium on Systems Theory, Tuskegee, AL, March 2005.

BISHOP, Bradley E., Associate Professor, "Control of Platoons of Nonholonomic Vehicles Using Redundant Manipulator Analogs," Institute for Electrical and Electronics Engineering (IEEE) International Conference on Robotics and Automation, Barcelona, Spain, April 2005.

BISHOP, Bradley E., Associate Professor, "Teaching Robot Design: Locomotion Beyond Differential Drive," American Society for Engineering Education (ASEE) Conference and Exposition, Portland, OR, June 2005.

BISHOP, Bradley E., Associate Professor and WICK, Carl E., Professor, "Analog Computation for Mobile Robotics Education," American Society for Engineering Education (ASEE) Conference and Exposition Portland, OR, June 2005.

BISHOP, Bradley E., Associate Professor, "Design and Control of Platoons of Cooperating Autonomous Surface Vessels," Seventh Maritime Transportation System Research and Technology Coordination Conference, Washington, DC, November 2004.

ESPOSITO, Joel M., Assistant Professor, "Adaptive RRT's for Validating Hybrid Robotic Control Systems," 6th International Workshop on the Algorithmic Foundations of Robotics, Zeist, Netherlands, July 2004.

ESPOSITO, Joel M., Assistant Professor, "Randomized Test Case Generation for Hybrid Systems: Adaptive Sample Biasing," American Control Conference, Portland, OR June 2005.

ESPOSITO, Joel M., Assistant Professor, "Promoting and Assessing Intuitive Understanding in a Junior-Level Modeling Course," American Society for Engineering Education (ASEE) Conference and Exposition, Portland, OR, June 2005.

FEEMSTER, Matthew G., Assistant Professor, "Tracking Control of an Underactuated Unmanned Underwater Vehicle," American Control Conference, Portland, OR, June 2005.

FEEMSTER, Matthew G., Assistant Professor, "Utilization of a Dynamometer/MATLAB Environment within a Linear Controls Design Project," American Society for Engineering Education (ASEE) Conference and Exposition, Portland, OR, June 2005.

KIRIAKIDIS, Kiriakos, Associate Professor, "H-Infinity Based Identification of Stiffness in the Presence of Uncertainty," American Society for Mechanical Engineers (ASME) International Mechanical Engineering Congress and Exposition, Anaheim, CA, November 2004.

KIRIAKIDIS, Kiriakos, Associate Professor, "H-Infinity D& T for Underwater Sensor Systems," Office of Naval Research (ONR) Torpedo DCL Winter Review, Newport, RI, February 2005.

KIRIAKIDIS, Kiriakos, Associate Professor, "Optimal Detection and Tracking of Torpedo Salvoes, Naval Academy Chapter of SIGMA XI, Annapolis, MD, February 2005.

KNOWLES, Kenneth A., Professor, "Pulse-Width Modulated Control for a Cold Water Diver Catalytic Heater Temperature Control System," Underwater Intervention 2005 International Conference, New Orleans, LA, February 2005.

LOLLINI, Christopher T., Midshipman 1/C, USN, GUSTAFSON, Erik H., Midshipman 1/C, USN, BISHOP, Bradley E., Associate Professor and WICK, Carl E., Professor, "Swarm Technology for Search and Rescue Through Multi-Sensor, Multi-Viewpoint Target Identification," Institute for Electrical and Electronics Engineering (IEEE) Southeastern Symposium on Systems Theory, Tuskegee, AL, March 2005.

O'BRIEN Jr., Richard T., Associate Professor, "Scale-Model Vehicle Analysis Using an Off-the-Shelf Scale-Model Testing Apparatus," American Control Conference, Boston, MA, July 2004.

O'BRIEN Jr., Richard T., Associate Professor, "Reduced-Order H-Infinity Filtering for Discrete-Time, Linear, Time-Varying Systems," American Control Conference, Boston, MA, July 2004.

O'BRIEN Jr., Richard T., Associate Professor, "H-Infinity Parameter Estimation for State-Space Models," American Control Conference, Boston, MA, July 2004.

O'BRIEN Jr., Richard T., Associate Professor, "An H-Infinity-based Detection and Tracking Method for Underwater Sensor Systems," Office of Naval Research Review, Arlington, VA, October 2004.

O'BRIEN Jr., Richard T., Associate Professor, "An H-Infinity-based Detection and Tracking Method for Underwater Sensor Systems," CTDCL Program Review, Newport, RI, February 2005.

O'BRIEN Jr., Richard T., Associate Professor, "A Unified Procedure for Discrete-Time Root Locus And Bode Design," American Control Conference, Portland, OR, June 2005.

PARIKH, Sarangi, P., Assistant Professor, "Usability Study of a Control Framework for an Intelligent Wheelchair," Institute for Electrical and Electronic Engineering (IEEE) International Conference on Robotics and Automation (ICRA) 2005, Barcelona, Spain, April 2005.

PARIKH, Sarangi, P., Assistant Professor, "A Framework for Shared Motion Control: Human-robot Augmentation with Applications to Assistive Technology," Ph. D. Dissertation Defense, University of Pennsylvania, Philadelphia, PA, March 2005.

PARIKH, Sarangi, P., Assistant Professor, "A Framework for Computer-mediated Motion Control," Mechanical Engineering and Applied Mechanics Departmental Seminar at University of Pennsylvania, Philadelphia, PA, August 2004.

PIEPMEIER, Jenelle A., Associate Professor, "The Use of MATLAB for Robotic Control in an Undergraduate Robotics Laboratory," American Society for Engineering Education (ASEE) Conference and Exposition, Salt Lake City, UT, June 2004.

PIEPMEIER, Jenelle.A., Associate Professor, "Analysis of Stereo Vision-based Measurements of Laboratory Water Waves," Institute for Electrical and Electronic Engineering (IEEE) International Geoscience and Remote Sensing Symposium, Anchorage, AK, September 2004.

TAN, Yong Chye, Midshipman 1/C, USN (Trident Scholar 2004) and BISHOP, Bradley E., Associate Professor, "Combining Classical and Behavior-Based Control for Swarms of Cooperating Robots," Institute for Electrical and Electronic Engineering (IEEE) 2005 International Conference on Robotics and Automation, Barcelona, Spain, April 2005.

WICK, Carl E., Professor, "USNA Systems Engineering Program," Office of the Secretary of Defense OSD (AT&L) Systems Engineering Forum, Annapolis, MD, April 2005.

ZIVI, Edwin L., Associate Professor, "Electric Ship Integration (ESI) Team Control Systems Perspective and Contributions," Office of Naval Research (ONR) Electric Ship Research and Development Consortium Control Architecture Workshop, Arlington, VA, May 2004.

ZIVI, Edwin L., Associate Professor, "Design of Robust Shipboard Power Automation Systems," International Federation of Automatic Control (IFAC) Control Applications in Marine Systems, Ancona, Italy, July 2004. (Invited Plenary Lecture)

ZIVI, Edwin L., Associate Professor, "Integrated Reconfigurable Intelligent Systems," Distributed Intelligence for Automated Survivability (DIAS) Program Review, The Johns Hopkins University Applied Physics Laboratory, Laurel MD, August 2004.

ZIVI, Edwin L., Associate Professor, "Control Strategies and Algorithms Panel Report," Distributed Intelligence for Automated Survivability (DIAS) Program Review, The Johns Hopkins University Applied Physics Laboratory, Laurel MD, August 2004.

ZIVI, Edwin L., Associate Professor, "Engineering Casualty Control Automation," ASNE Reconfiguration and Survivability Symposium, Atlantic Beach, FL, February 2005. (Invited Plenary Lecture)