Weapons and Systems Engineering Department

Professor Terrence E. Dwan
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 the 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 three Trident Scholars in the Weapons and Systems Engineering Department. The scholars engaged in extensive research projects 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 advisor. These advisors 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

Redundant Manipulator Analogs in Control for Platoons of Autonomous Underwater Vehicles

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

This project focused on the development of control methods for cooperating swarms (or platoons) of Autonomous Underwater Vehicles (AUVs). Methods developed rely on techniques common in redundant manipulator control, and allow for platoon formation synthesis in real time with limited computational burden. The approaches investigated also allow for easy combination of systems-theoretic control methods and behavior-based reactive strategies in a system that can still be guaranteed to meet specific performance criteria.

Decentralized methods for application of the proposed control were investigated as well, and it was seen that the architecture was amenable to decentralization with minimal communication burden.

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 pilot assistance for small manned craft in littoral scenarios. This work will be based on the application of passive control-limitation technologies rather than complete craft autonomy. In much the same way that anti-lock braking systems limit the driver's control of the brake pads in a car, the driver assist technologies will passively limit the pilot's control over the ship's actuation in order to prevent accidents and limit wake effects in littoral environments and crowded shipping lanes and harbors.

The basis for these techniques will be environmental sensing and appropriate modeling. A number of sensing modalities will be investigated, and efficient techniques developed by which the control system can monitor the environmental state and thereby carry out appropriate actions and provide valuable information to the pilot. This sensing system will then be coupled to a control system to generate a 'fly-by-wire' style pilot interface with safety limits on actuation as well as performance enhancing control features.

H-Infinity Control Theoretic Methods for Antennae

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

This project investigated two important problems relevant to antennae applications. The filtering problem involved the estimation of received data from noisy measurements as in radar applications. The control problem involved the regulation of the flow of information to and from an antenna as in communication networks. The dynamics of antenna systems are complex and exact mathematical models are difficult or impossible to obtain from first principles. Most of the existing design methods require an accurate model of the system and are unable to accommodate problems of this type. In this project, these two problems were considered in a very general context and the antennae were modeled as uncertain, nonlinear, time-varying systems. Existence of solutions of both problems is being addressed for an uncertain nonlinear or time-varying model. Design and synthesis procedures for the filtering and control problems are being developed for linear, time-varying systems with potential extensions to the general problem. (This project has completed its second and last year.)

Electric Helicopter Surveillance Vehicle Demonstration

Researchers: Professor Kenneth A. Knowles and Dr. David Brown
Sponsor: Office of Naval Research (ONR)

The objective of the Electric Helicopter Surveillance Vehicle is to demonstrate a 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 Kiriakidis
Sponsor: Office of Naval Research (ONR)

The paper presents a novel approach to estimate the angles of arrival recursively as measurements of incident signals are received along a sensor array. Using a single snapshot and without any statistical assumptions, the proposed method employs a robust performance criterion, which is based on worst-case gain minimization. The criterion aims to reduce the estimation error induced by worst-case amplitude and phase perturbations as well as additive noise in the array model. An algorithm that guarantees the criterion---within a first-order approximation---is developed and shown to converge. Moreover, instead of using a trial-and-error method to find a constant, minimum worst-case gain, the minimum worst-case gain is updated as each sensor measurement is processed. A step-by-step implementation of the algorithm is presented and its computational complexity is analyzed. The performance of the new approach is evaluated by simulating the estimation algorithm for a linear array.

Uncalibrated Vision-Guided Robotic Control

Researcher: Assistant Professor Jenelle A. Piepmeier
Sponsor: Naval Academy Research Council (ONR-NARC)

This research produced experimental results for a model independent, vision-guided, robotic eye-in-hand control method. The controllers investigated implement a dynamic Gauss-Newton method and use nonlinear least squares optimization. The combined camera/robot model is approximated in a dynamic Jacobian estimation strategy, allowing servo control to be applied to systems without requiring a robotic kinematic model or a calibrated camera model. Error velocity estimation is done simultaneously with Jacobian estimation in a partitioned matrix method. The control method is independent of the type of robot, the type of camera, and number of cameras. Several dynamic Gauss-Newton controllers were tested at varying target speeds for a two degree-of-freedom planar robot. This control method was also found to be robust to variations in kinematic model and camera orientation validating the uncalibrated nature of the control. The results are applicable to not only manipulator types of robots, but also other systems such as mobile robots or unmanned underwater vehicles.

Impact of Cross-Link Delays on Spacecraft Formation Control

Researchers: Associate Professor George E. Piper and
Associate Professor John M. Watkins
Sponsor: NASA/Goddard Space Flight Center

In this work, the ability for tight formation control in the presence of communication and measurement delays is investigated. The paper discusses cross-link requirements for formation control and compares centralized and decentralized control strategies. A simple two degree-of-freedom model with communication delays is introduced for analysis. A typical approach for systems with small time delays is to base the design on a nominal system model that does not contain the time-delays. The limitations of this approach on stability and closed-loop bandwidth are discussed. Finally, the time delay is considered in the design of state-feedback with integral feedback controllers. The effects of the time-delay on stability, stability margins, and bandwidth are investigated.

Disk Drive Monitor and Simulator

Researchers: Professor Carl E. Wick and
Associate Professor Svetlana Avramov-Zamurovic
Sponsor: National Institute of Standards and Technology (NIST)

This project supports the testing and standardization of computer forensics software by the National Institute of Standards and Technology (NIST). Computer forensic efforts often entail the examination and collection of data from personal computer hard disk drives. If the data taken from disks is to be used as evidence in court proceedings, there must be established confidence that the software does not change the data in any manner during collection. The National Institute of Standards and Technology has a program that rigorously tests forensics software to determine its potential interaction with

the data the programs collect. The disk drive monitor and simulator is a device that is being constructed that will electrically monitor disk drive activity external to any software. The device will record and report any disk drive accesses and will be able to insert error codes in the stream to test disk program reactions to errors that may occur during data collection.

Electric Power Network Efficiency and Security (EPNES)

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

Control system requirements for highly automated and survivable future electric warships have been articulated to stimulate and unify interdisciplinary research conducted under the joint NSF/ONR Electric Power Networks Efficiency and Security (EPNES) initiative. This ONR challenge problem focuses on continuity of control for interdependent shipboard engineering and damage control systems under hostile conditions. The mission statement for these Hull, Mechanical, Electrical & Damage Control (HME&DC) systems may be summarized as: Provide continuous mobility, power, and thermal management for shipboard combat systems despite major disruptions involving cascading failures. This challenge problem is prototypical of analogous complex, interdependent systems including the national power grid, military and civilian infrastructure, and transport systems. These nonlinear, distributed, heterogeneous, variable structure systems contain dynamically interdependent subsystems. Mission/life critical system integrity and fault tolerance requirements demand dependable continuity of service. Innovative, dependable, and affordable control system architectures, strategies, algorithms, methods and tools are sought.

The first NSF/ONR Partnership in Electric Power Networks Efficiency and Security (EPNES) program solicitation, NSF 02-041, was posted Dec 21, 2001 with source selection leading to multi-year grants awarded during the summer of 2002. ONR technical requirements and benchmark simulation where presented at the EPNES awardees kickoff meeting. This MATLAB/Simulink power automation benchmark system has been disseminated to grantees. A second NSF/ONR Partnership in Electric Power Networks Efficiency and Security (EPNES) program solicitation NSF-02-188, closed on February 3, 2003. Source selection for second set of awardees is complete. The second EPNES awardees kickoff meeting will coincide with the annual review of the first year awardees.

Electric Ship Integration

Researchers: Assistant 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 investigators are part of a collaborative effort that includes faculty from MIT, Purdue University, and University of Missouri at Rolla. The effort specifically involves the integration of research, analyses, software and hardware tools, monographs, and curricula to support multidisciplinary ship design, power system analysis, and automation engineering. The USNA technical thrust is in the area of automation engineering. Initial have focused on the development of an automation laboratory and the structuring of an undergraduate course in automation. The investigators have specified, procured, and configured the equipment and software for an automation systems research laboratory located in Maury 103. This distributed control prototyping environment has been used to support one Trident project, two Bowman projects, and three senior design projects. Specifically, three students collaborated to design, assemble, and exercise a low-power three-zone power system and associated control system. This system successfully reconfigured the power system upon detection of selected faults and failures. As part of this effort, power converter modules have been designed and will be integrated into the system. The Systems Engineering automation course curricula including lecture, laboratory and student projects has been defined and preparation of course materials, including a textbook in the form of an automation monograph are underway. A complimentary Electrical Engineering power systems course for non-EE majors has been outlined and preparation of a teaching manuscript has been initiated. This material will also support current core courses as well as future multidisciplinary engineering offerings.

Independent Research

Test Generation for Embedded Control Systems

Researcher: Assistant Professor Joel M. Esposito

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, 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 an 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 numerical optimal control based technique is presented. The tradeoff between computational cost and authenticity is explored.

Learning Based Estimator for Nonlinear Periodic Disturbances for Magnetic Levitation Systems

Researcher: Assistant Professor Matthew G. Feemster

A position regulation control strategy is currently under development for a magnetic levitation system operating in the presence of a bounded, nonlinear, periodic disturbance. The proposed controller will utilize a saturated control force input in conjunction with a learning based disturbance estimator in an attempt to regulate the target mass to a desired set point position despite the actuator's unidirectional limitation of exerting only an attractive force on the target mass (i.e., the control input can only generate an attractive force while the earth's gravitational field is utilized to produce the repulsive action).

Virtual SCORBOT

Researcher: Professor Kenneth A. Knowles

The SCORBOT laboratory robot used in the Robotics Laboratory has been interfaced with MATLAB to permit real-time control. When testing new control programs, students often end up crashing the robot end-effector into the work surface, or attempt to position the arm in postures that can potentially harm the device. A virtual SCORBOT MATLAB graphics program was created to permit safe debugging of student-developed MATLAB robot control programs. The program uses the same robot commands as the actual robot, but with a "v" appended to the beginning of each command. A moving stick graphic of the robot arm and end-effector is displayed on the computer CRT to show the student the expected manipulator response to his/her control program. The basic program has been provided to the students, but it will not be integrated into the curriculum until this coming fall semester of ES450. As with all complex programs, some additional refinements are expected to be required.

Midshipman Research Course Projects

Autonomous Robot Formation Control

Researcher: Midshipman 1/C Brian E. Sofen, USN
Adviser: Associate Professor Bradley E. Bishop

This project focused on development of a physical test bed that could be used for formation control of platoons (or swarms) of cooperating Unmanned Ground Vehicles, as well as a hardware-in-the-loop simulation of platoon controllers for aerial and underwater vehicles as well. The test bed included three separate wheeled robots, wireless communications, wireless visual sensing and centralized control.

T-HAV: A Tracked Hydraulic Autonomous Vehicle

Researcher: Midshipman 1/C Perry B. Akin, USN
Adviser: Associate Professor Bradley E. Bishop

This research project focused on the development of a medium-sized autonomous vehicle for surveillance, mine countermeasures, etc. The vehicle was designed to include an internal combustion engine and hydraulic actuators, providing significant power for low weight. Specialized tracks were designed to allow for good traction while still allowing for high mobility.

Next Generation Planetary Rover

Researcher: Midshipman 1/C Jeremy L. Searock, USN
Adviser: Associate Professor Bradley E. Bishop

This research project focused on the development of a new concept planetary rover with capabilities that exceed those of the Mars Sojourner by significant margins. The vehicle designed includes two platforms with passive compliance coupled through an articulated arm that allows for novel locomotion over a variety of terrain. Power supplies, motors, wheels and vehicle geometry were optimized for the proposed method of locomotion, which was seen to be effective on the target terrain.

Flexibility Investigation Into Community Robotics Using Supervisory Control

Researcher: Midshipman 1/C Joshua M. Hawkes, USN
Adviser: Associate Professor Kiriakos Kiriakidis

The purpose of this research is to build on current research in the area of community robotics. The project examines the possibility of adding one or more robots to the group and reconfiguring the new group to maintain task completion. The project uses supervisory control in order to enable the team of robots to coordinate their assignments. This research builds on similar projects using the same messaging scheme developed earlier. Conventional control systems theory does not work with a group of robots trying to complete several tasks under the coordination of a supervisor. This project has required research in new control system theories as well as developing new techniques of intercommunication between the robots acting autonomously from one another.

Double Integrator Control

Researchers: Midshipman 1/C Eric P. Boernke, USN
and Midshipman 1/C Lora M. Gorsky, USN
Adviser: Associate Professor Richard T. O'Brien, Jr.

The aim of this project is to model a position feedback controller for use as an automatic vehicle steering control system for a small automobile. A proposed double integrator control algorithm will be theoretically and experimentally investigated in order to establish design guidelines, to compare the proposed algorithm with existing ones, and to prove the feasibility of the proposed controller. The control system uses samples of the output of a continuous-time, linear controller to determine the amplitude of a pre-determined, piecewise constant, control signal. The motion of the double integrator system is specified during the sampling interval. The evaluation of the proposed algorithm will involve a theoretical study using SIMULINK simulations and the experimental implementation using MATLAB Real-time Tools. In the theoretical study, the design guidelines of the double integrator control system will be investigated. After the design procedure is established, the robustness of the system this algorithm will be investigated for the case of model uncertainty defined as additional poles and zeros in the left hand plane. Finally, this control algorithm will be evaluated by comparing it to an existing benchmark, the Bernstein criteria. In the experimental evaluation, MATLAB Real-time Tools will be used to evaluate the algorithm by achieving control of a double integrator plant.

Midshipman Design Projects

The Claw
Researchers: Midshipmen 1/C Eric J. Adler
and Jonathan D. Leewarner, USN
Advisers: Professor Carl E. Wick
and LCDR William S. Pendergrass, USN

Tracked Hydraulic Autonomous Vehicle
Researcher: Midshipman 1/C Perry B. Akin, USN
Advisers: Associate Professor Bradley E. Bishop
and Major Todd W. Ferry, USMC

Fighting Fountains – Musical Water Display
Researchers: Midshipmen 1/C Phillip T. Ash, John A. Dalby,
David I. Fuller and Mary E. Kane, USN
Advisers: Assistant Professor Edwin L. Zivi
and Major Todd W. Ferry, USMC

Automated Underwater Vehicle (AUV)
Researchers: Midshipmen 1/C Kathryn T. Baehr, Keith R. Buckingham,
Jonathan T. Gibson, Rudolf A. Hawkes, Steven A. MacGillis,
Bryan A. Peterson, and Daniel M. Singer, USN
Advisers: Professor Carl E. Wick and
Lieutentant Colonel Randy P. Broussard, USAF

Systems Ball
Researchers: Midshipmen 1/C Daniel A. Bailey
and Andrew S. Downes, USN
Advisers: Assistant Professor Edwin L. Zivi
and Captain Owen G. Thorp, III, USNR

Self-Righting Kayak
Researchers: Midshipmen 1/C Bryan N. Blackburn,
Paul J. Nicholas and Christopher C. Radke, USN
Advisers: Professor Robert DeMoyer and
Lieutenant Commander Charles B. Lynch, USN

Robo Cup
Researchers: Midshipmen 1/C John R. Blackford,
Justin P. Cooper and Baljot S. Mahal, USN
Advisers: Professor Kenneth A. Knowles and
Lieutenant Commander Brian M. Riley, USN

Double Integrator Control
Researchers: Midshipmen 1/C Eric P. Boernke
and Lora M. Gorsky, USN
Advisers: Associate Professor Richard T. O'Brien, Jr.
and Commander Allison D. Webster-Giddings, USN

Remote Controller Electronic Surveillance Helicopter
Researchers: Midshipmen 1/C David S. Bonfante,
Victor H. Lee and Brandon E. Sisco, USN
Advisers: Professor Kenneth A. Knowles,
Lieutenant Commander Jennifer L. Nicholls, USN
and Lieutenant Commander Curtis S. Lindsay, USNR

Good or No Good
Researcher: Midshipman 1/C Eric A. Cahill, USN
Advisers: Assistant Professor Jenelle L. Piepmeier
and Commander Allison D. Webster-Giddings, USN

Smooth Operator vs. 2K3
Researchers: Midshipmen 1/C Brent J. Cantrell
and Aaron V. Kakiel, USN
Advisers: Professor Thomas E. Bechert
and Lieutenant Commander Pierre Hilaire, USN

Systems Ball
Researchers: Midshipmen 1/C Brian G. Carbaugh
and Derek C. Jaskowiak, USN
Advisers: Professor Terrence E. Dwan
and Major Todd W. Ferry, USMC

Auto Caddy
Researchers: Midshipmen 1/C Justin E. Carlson
and Mitchell P. Grant, USN
Advisers: Professor Kenneth A. Knowles
and Lieutenant Commander Charles B. Lynch, USN

Centerline Candidate
Researchers: Midshipmen 1/C David T. Ciha,
Michael J. O'Brien and James A. Richardson, USN
Advisers: Associate Professor Richard T. O'Brien, Jr.
and Lieutenant Colonel Randy P. Broussard, USAF

TV Sound Control
Researchers: Midshipmen 1/C Thomas C. Denton,
Kenneth R. Greenfield and Patrick J. Hudock, USN
Advisers: Professor Robert DeMoyer
and Commander Allison D. Webster-Giddings, USN

Robo Roadie
Researchers: Midshipmen 1/C Mark D. Cochran
and Jeremy R. Winkle, USN
Advisers: Assistant Professor Joel M. Esposito
and Lieutenant Commander Curtis S. Lindsay, USNR

Systems Ball
Researchers: Midshipmen 1/C Jack C. Dietz
and Luke S. Saladyga, USN
Advisers: Visiting Professor Robert H. Small
and Lieutenant Commander Charles B. Lynch, USN

Unmanned Aerial Vehicle
Researchers: Midshipmen 1/C Bryan A. Dudley,
James R. Friedlein, Christopher B. Hogan,
Emanuel M. Tsikalas and Christian G. Ward, USN
Advisers: Associate Professor George E. Piper
and Lieutenant Michael J. Supko, USN

Automatic Bicycle Gear Shift
Researchers: Midshipmen 1/C Stephen P. Eckhart
and Kevin K. Shikuma, USN
Advisers: Associate Professor Svetlana Avramov-Zamurovic
and Lieutenant Craig M. Payne, USNR

Self-Tuning Guitar
Researchers: Midshipmen 1/C Ryan M. Fisher
and Kevin M. McElroy, USN
Advisers: Associate Professor Kiriakos Kiriakidis
and Commander Allison D. Webster-Giddings, USN

Emergency Vehicle Detecting Car Radio Damper
Researchers: Midshipmen 1/C Joshua W. Fogle, Adam R. Sipp
and Andrew W. Wyrick, USN
Advisers: Assistant Professor Edwin L. Zivi
and Lieutenant Commander Pierre Hilaire, USN

The Unit: An Autonomous Pitching Machine
Researchers: Midshipmen 1/C Michael L. Frisby,
Rudolf A. Hawkins and Thomas C. Parker, USN
Advisers: Professor Thomas E. Bechert
and Commander Juan A. Navarrete, USN

Robo-Putter
Researchers: Midshipmen 1/C Peter K. Fukushima
and Gregory C. Sham, USN
Advisers: Associate Professor John M. Watkins
and Lieutenant Commander Brian M. Riley, USN

Full Count Bases Loaded
Researchers: Midshipmen 1/C Matthew B. Furquan, Alan M. Giles,
Stephen C. Harrington and Chad S. Pollack, USN
Advisers: Assistant Professor Joel M. Esposito
and Lieutenant Commander Charles B. Lynch, USN

Systems Ball
Researchers: Midshipmen 1/C Timothy W. Gleason
and Jared M. Jakubowski, USN
Advisers: Associate Professor Kiriakos Kiriakidis
and Lieutenant Commander William S. Pendergrass, USN

Systems Ball
Researchers: Midshipmen 1/C Peter C. Glynn,
Steven N. Kuehn and Michael E. Mullen, USN
Advisers: Professor Terrence E. Dwan
and Captain Owen G. Thorp III, USNR

Systems Ball
Researchers: Midshipmen 1/C Sinead I. Gordon
and Andrew S. Kindred, USN
Advisers: Professor Terrence E. Dwan
and Lieutenant Commander Jennifer L. Nicholls, USN

The F. I. D. O. Project
Researchers: Midshipmen 1/C Russell S. Griffith,
Thomas C. Saenz and Charles L. Walker, USN
Advisers: Assistant Professor Jenelle L. Piepmeier
and Lieutenant Commander Curtis S. Lindsay, USNR

Battlebot
Researchers: Midshipmen 1/C Ryan C. Heineman, Kevin J. Jordan,
Thomas J. Murray, Matthew A. Perkins
and William S. Russell, USN
Advisers: Associate Professor Bradley E. Bishop
and Lieutenant Commander William S. Pendergrass, USN

Spacecraft Autonomous Rendezvous and Capture Systems
Researcher: Midshipman 1/C Kin Leong Ho, USN
Advisers: Associate Professor George E. Piper
and Lieutenant Commander Curtis S. Lindsay, USNR

Snake-Like Robot
Researchers: Midshipmen 1/C Brian E. Hollier,
Bret J. Knickerbocker and Adam B. Miller, USN
Advisers: Associate Professor John M. Watkins
and Lieutenant Craig M. Payne, USNR

Potato Gun with Optical Tracking
Researchers: Midshipmen 1/C Robert P. Hortman
and Christopher S. Stuart, USN
Advisers: Assistant Professor Jenelle L. Piepmeier
and Lieutenant Commander Brian M. Riley, USN

Diver Heater Using Hydrogen Catalytic Reactions
Researchers: Midshipmen 1/C Brandon J. House
and Edward S. Poitevent, USN
Advisers: Associate Professor Svetlana Avramov-Zamurovic
and Commander Allison D. Webster-Giddings, USN

Boxing Head Gear Testing Equipment
Researchers: Midshipmen 1/C Eric C. Hui,
Robert D. Salire and Roberto W. Vilanueva, USN
Advisers: Associate Professor George E. Piper
and Commander Juan A. Navarrete, USN

Vehicle Mounted Gun with Head Tracking Fire Control
Researcher: Midshipman 1/C Kenneth H. Javes, USN
Advisers: Assistant Professor Matthew G. Feemster
and Lieutenant Commander Craig M. Payne, USNR

Solar Powered Car
Researchers: Midshipmen 1/C Nathaniel L. Jennings
and David A. Krasik, USN
Advisers: Associate Professor Kiriakos Kiriakidis
and Lieutenant Commander Pierre Hilaire, USN

Systems Ball
Researchers: Midshipmen 1/C Clay I. Johnson,
Joseph A. Maxwell and Thomas H. Van Hoozer, USN
Advisers: Professor Terrence E. Dwan
and Lieutenant Michael J. Supko, USN

Systems Ball
Researchers: Midshipmen 1/C Conor P. Latham
and Quinn P. Nichols, USN
Advisers: Assistant Professor Matthew G. Feemster
and Lieutenant Commander Charles B. Lynch, USN

Systems Ball
Researchers: Midshipmen 1/C Christopher J. Longabaugh,
Nicholas M. Parker and Nadia Sheikh, USN
Advisers: Assistant Professor Joel M. Esposito
and Lieutenant Colonel Randy P. Broussard, USAF

Induction Coil Gun
Researchers: Midshipmen 1/C Justin M. Luczyk
and Lawrence D. Malone, USN
Adviser: Associate Professor Kiriakos Kiriakidis

Recon Soda Patrol
Researchers: Midshipmen 1/C Jason A. Martinez,
Richard A. Stephenson and Charles K. Walker, USN
Advisers: Professor Robert DeMoyer
and Lieutenant Michael J. Supko, USN

Systems Ball
Researchers: Midshipmen 1/C Kimberly R. Martinez
and Jamis M. Seals, USN
Advisers: Professor Carl E. Wick
and Lieutenant Commander Pierre Hilaire, USN

3-Axis Attitude Control of MIDSTAR Satellite
Researcher: Midshipman 1/C Jaris C. McClain, USN
Advisers: Associate Professor George E. Piper
and Commander Juan A. Navarrete, USN

Precision Formation Driving Robots
Researchers: Midshipmen 1/C Carter W. McCrary
and David W. Van Dyne, USN
Advisers: Associate Professor John M. Watkins
and Lieutenant Commander Jennifer L. Nicholls, USN

Hovercraft to Track Underwater Targets
Researchers: Midshipmen 1/C Ricky F. Mui
and Yeonjin Yang, USN
Advisers: Associate Professor Richard T. O'Brien, Jr.
and Lieutenant Colonel Randy P. Broussard, USAF

SAE Car Project
Researchers: Midshipmen 1/C Alexander Y. Nusraty
and Devin G. Phillabaum, USN
Advisers: Assistant Professor Matthew G. Feemster
and Lieutenant Commander Curtis S. Lindsay, USNR

Lacrosse Ball Feeder
Researchers: Midshipmen 1/C Tajuddin I. Sabree
and Jason P. Schaengold, USN
Advisers: Professor Thomas E. Bechert
and Commander Juan A. Navarrete, USN

The Next Generation Planetary Rover
Researcher: Midshipman 1/C Jeremy L. Searock, USN
Advisers: Associate Professor Bradley E. Bishop
and Lieutenant Commander Jennifer L. Nicholls, USN

Mobile Mine Searching Robot
Researchers: Midshipmen 1/C Douglas B. Shores
and Ryan D. Whitty, USN
Advisers: Visiting Professor Robert H. Small
and Lieutenant Michael J. Supko, USN

Control of Autonomous Robotic Vehicles in Formation
Researcher: Midshipman 1/C Brian E. Sofen, USN
Advisers: Associate Professor Bradley E. Bishop
and Lieutenant Craig M. Payne, USN

Gamma Ray Detection of Plutonium in a Maritime Cargo Container
Researcher: Midshipman 1/C Joseph S. St. John, USN
Advisers: Associate Professor Svetlana Avramov-Zamurovic
and Lieutenant Commander Brian M. Riley, USN

Trident Scholar Projects

Model Vehicle Analysis for the Design of a Steering Controller (Trident Report # 309)
Researcher: Midshipman 1/C Philip C. Hoblet, USN
Advisers: Associate Professor Richard T. O'Brien, Jr. and
Assistant Professor Jenelle L. Piepmeier
Sponsor: Office of Naval Research (ONR)

This Trident project investigates the design of a driver assistance steering controller. The initial goal of this research was to modify an off-the-shelf radio controlled (RC) car to make it dynamically similar to full-size automobiles. Using ratios of vehicle parameters (known as Π groups), the Buckingham-Pi theorem was applied to analyze both the scale vehicle and a variety of full-size vehicles. To establish the standards by which to modify the RC car, the Π groups of actual automobiles have been calculated using published data.

Before any of the RC car's Π groups could be calculated, different parameters of the RC car needed to be measured. Based on comparisons of corresponding Π groups, appropriate modifications have been made to achieve dynamic similitude. A control system was designed to control the lateral and longitudinal position of the RC car. The control system stabilized the vehicle but will require further tuning to achieve accurate tracking.

After performing an experiment consisting of a lane change maneuver, the data from the RC car was compared to data from similar experiments using full-size automobiles. Similarity between the results verifies the dynamic similitude of the RC car and the full-size automobiles.

Development of an Urban Search and Rescue Robot (Trident Report # 311)

Researcher: Midshipman 1/C Bryan M. Hudock, USN
Advisers: Associate Professor Bradley E. Bishop and
Assistant Professor Frederick L. Crabbe IV (Computer Science Department)
Sponsor: Office of Naval Research (ONR)

The goal of this project was the design and construction of an urban search-and-rescue robot. The end result of this project was a robot with a versatile mobility and a set of simulation tools that can be used to design and tune gaits for effective locomotion in a variety of terrain with very little operator effort.

A Study of Magnetically-Coupled 2-D Reconfigurable Modular Robots (Trident Report # 314)

Researcher: Midshipman 1/C Sean A. Patterson, USN
Advisers: Professor Kenneth A. Knowles and
Associate Professor Bradley E. Bishop
Sponsor: Office of Naval Research (ONR)

This Trident Scholar project consisted of the development and investigation of identical modular autonomous robots that used only active magnetic forces to self-reconfigure and passive magnetic forces to maintain themselves in a network of independent modular robots. The resultant modular group configurations have the potential to provide useful functions not possible by the individual units.

The goals of this project were threefold: (a) to develop and determine the effectiveness of a network that utilizes magnetically-connected and actuated modules; (b) to develop suitable self-reconfiguration algorithms; and (c) to extrapolate this macro scale network to future micro scale networks. Implementation of these goals was done in two major phases. Initially, sophisticated generic independent robot modules were designed and constructed to show that several modules could autonomously self-reconfigure in a laboratory network. The design of these modules was iteratively improved to arrive at a fully functional design. The second phase involved developing generic imbedded software for each module to permit the small network to move and self-reconfigure. The performance of the active magnetic actuation, passive magnetic latch robotic modules that were developed was observed to be comparable, but not necessarily superior to existing mechanically linked designs on the macro scale. The use of magnets vice mechanical actuators and latches, however, provides promise of being superior in micro scale networks of reconfigurable robots.

Publications

Journal (Refereed) Manuscripts

Fierro R., Das, A., Spletzer, J., ESPOSITO, Joel M., Assistant Professor, Kumar, V., J. P., Ostrowski, Pappas, G., Taylor, C. J., Hur, Y., Alur, R., Lee, I., Grudic, G., and Southall, J., "A Framework and Architecture for Multi-Robot Coordination,"

International Journal of Robotics Research (IJRR), Oct - Nov 2002, Vol. 21, No. 10-11, pp. 977-995.

This paper describes the framework and the software architecture for the development of multiple autonomous robots in an unstructured and unknown environment, with applications ranging from scouting and reconnaissance, to search and rescue, to manipulation tasks, to cooperative localization and mapping, and formation control. Our software framework allows a modular and hierarchical approach to programming deliberative and reactive behaviors in autonomous operation. Formal definitions for sequential, hierarchical and parallel composition allow the bottom-up development of complex software systems. This paper demonstrates the algorithms and software on an experimental test-bed that involves a group of car like robots, each using a single omni-directional camera as a sensor without explicit use of odometery.

Behal, A., FEEMSTER, Matthew G., Assistant Professor, Dawson, D. M., and Haste, D., "An Improved Indirect Field Oriented Controller for the Induction Motor," *Institute for Electrical and Electronic Engineering* (*IEEE) Transactions on Control System Technology*, Vol. 11, No.2, pp. 248-252.

This paper illustrates how the standard indirect field oriented controller (IFOC) commonly used in current-fed induction motor drives can be modified to achieve global exponential rotor velocity/rotor flux tracking. The modifications to the IFOC scheme, which involve the injection of nonlinear terms into the current control input and the so-called desired rotor flux angle dynamics, facilitate the construction of a standard Lyapunov stability argument. The construction of a standard Lyapunov exponential stability argument allows one to easily design adaptive controllers to compensate for parametric uncertainty associated with the mechanical load.

PIEPMEIER, Jenelle A., Assistant Professor, BISHOP, Bradley E., Associate Professor and KNOWLES, Kenneth A., Professor, "Modern Robotics Engineering Education," *Institute for Electrical and Electronic Engineering* (*IEEE) Robotics and Automation Magazine*, Vol. 10, No.2, June 2003, pp. 33-37.

This paper describes the three basic principles of robotics education in the modern environment, and contrasts the traditional teaching style used in a majority of engineering classes with that necessary for a rapidly developing field such as robotics. Our basic tenet is that a modern roboticist must have three characteristics: knowledge, experience and insight. While traditional education methods focus on knowledge and experience through the standard lecture-laboratory cycle, we submit that insight is the key to a complete robotics education. Insight cannot be gained from textbooks and laboratory experiments alone, as these tend to focus on merely academic rather than global and societal issues. A discussion of the techniques used at the United States Naval Academy (USNA) is presented to inform, educate, and motivate students in the field of robotics.

PIPER, George E., Associate Professor, WATKINS, John M., Associate Professor, Leitner, Jesse, and Markley, Landis, "Disturbance Reduction System Control Design for the LISA Mission," *Journal of Guidance, Control, and Dynamics*, May 2002.

The Laser Interferometer Space Antenna (LISA) mission will consist of a three spacecraft formation acting as a large interferometer. The spacecraft formation will measure the distortion of space caused by passing gravitational waves. Each spacecraft will contain two shielded proof masses that define the optical arms of the interferometer. To mitigate the effects of external disturbances, the LISA Disturbance Reduction System will control the spacecraft to fly drag-free trajectories with reference to their respective proof masses. This paper investigates control design issues associated with the LISA Disturbance Reduction System (DRS). In particular, this paper presents a 2 degrees-of-freedom (DOF) model representing a spacecraft with a single proof mass. With this model, key control design issues are identified. A Linear Quadratic Gaussian (LQG) controller design is then presented to illustrate the feasibility of the DRS control concept. A 3 DOF model is used to explore the DRS implications of a spacecraft with two proof masses.

PIPER, George E., Associate Professor, WATKINS, John M., Associate Professor, WICK, Carl E., Professor, and AVRAMOV-ZAMUROVIC, Svetlana, Associate Professor, "On the Design of an Electronic Muffler - A DSP Based Capstone Design Project," *Computers in Education Journal*, Vol. XII, No. 3, July-September 2002, pp. 42-46.

Active control of noise has been an emerging technology for the past two decades. Active noise control (ANC) is an attractive means to achieve large amounts of noise reduction in a small package, particularly at low frequencies, where passive noise control may be impractical. While the concept of ANC has long been established, the technological means for implementing ANC have only recently become available. With the advent of high-speed digital signal processors (DSPs) and modern signal processing methods, ANC is now becoming a reality.

This paper presents an interesting undergraduate design project involving ANC. In their capstone engineering design course students designed and built a prototype ANC system that successfully demonstrated the concepts of an electronic muffler. The heart of the project centered on the popular Analog Devices' SHARC DSP evaluation module (EVM). This paper discusses ANC concepts and the electronic muffler, the students design project, and the pedagogical outcome.

ZIVI, Edwin L., Assistant Professor, and PIEPMEIER, Jenelle A., Assistant Professor, "Dynamic System Animation Within a SIMULINK Laboratory Environment," *Computers in Education Journal,* Vol. 12, No. 3, July-September 2002, pp. 58-62.

Recent innovations in the animation of student developed, laboratory simulations have been found to significantly improve student understanding and enthusiasm. This animation can be implemented using MATLAB s-functions that are typically called from a SIMULINK simulation. These rudimentary animations have been found to be relatively easy to construct and well received by students. General observations and recommendations are developed from specific examples, hints, and experiences. Runtime animation has been found to be a valuable complement to the existing capability to visually construct the simulation model. S-function animations have been found to be composed of two primary elements: reusable interface/initialization templates and animation specific graphics. To date, animations have been developed solely as part of faculty course preparation. These animations have been found to efficiently leverage MATLAB's high level programming features to provide an effective teaching tool.

Conference Proceedings

Alur, R., Dang, T., ESPOSITO, Joel M., Assistant Professor, Hur, Y., Ivancic, F., Kumar, V., Lee, I., Mishra, P. Pappas, G. J., and Sokolsky, O., "Hierarchical Modeling and Analysis of Embedded Systems," *Proceedings of the Institute for Electrical and Electronic Engineering (IEEE)*, Vol. 91, No. 1, pp. 11-28.

This paper describes the modeling language CHARON for modular design of interacting hybrid systems. The language allows specification of architectural as well as behavioral hierarchy and discrete as well as continuous activities. The modular structure of the language is not merely syntactic, but is exploited by analysis tools and is supported by a formal semantics with an accompanying compositional theory of refinement. This paper illustrates the benefits of CHARON in the design of embedded control software using examples from automated highways concerning vehicle coordination.

AVRAMOV-ZAMUROVIC, Svetlana, Associate Professor, Waltrip, Bryan, Koffman, Andrew and PIPER, George E., Associate Professor, "Straightforward Design of Accurate Inductive Voltage Dividers," *Proceedings of the 2002 American Society for Engineering Education (ASEE) Annual Conference*, Montreal, Canada, June 2002. (CD-ROM)

The United States Naval Academy is an undergraduate school with a successful engineering program. An underlying philosophy in the Systems Engineering Department is to emphasize hands-on experience while maintaining a solid theoretical background. To realize this principle, both teachers and students face many challenges. In this paper an attempt is made to teach students how to build a very accurate ac voltage divider. The desired accuracy is better than a part per million, so it implies building a transformer-based divider. The idea is to bridge the gap between the state-of-the-art achievements in modern research and the undergraduate level of expertise.

There are a number of applications that use very precise voltage ratio devices, but one of the most common is in impedance bridges. Measurement bridges are constructed in such a way that they allow comparison of a standard unit and a unit under test. The standard and the device under test are connected in series. The impedance of a device under test is calibrated by finding the voltage ratio of the serial connection (see Figure 1.). In calibration laboratories, the impedance of resistors, capacitors, and inductors is tested using alternating current. Very often in physical experiments, the same concept is used to determine the properties of materials. The capacitance seems to be the most often measured quantity. In this paper we will concentrate on presentation of voltage ratio devices. From Figure 1 it can be seen that the voltage ratio is obtained using an inductive voltage divider.

There are a number of references that give technical details on inductive voltage divider design [1] [2]. But those papers and books are written by engineers deeply involved in research, for engineers doing the same. Our goal is to present a straightforward and easily comprehensible lecture on voltage divider design.

AVRAMOV-ZAMUROVIC, Svetlana, Associate Professor, Waltrip, Bryan, Koffman, Andrew, "Balancing Procedure for an IVD Bridge," *Proceedings of the 2003 Instrumentation and Measurement Technology (IMTC) Conference*, Vail, CO, 20-22 May 2003. (CD-ROM)

This paper presents a detector balancing procedure for a bridge based on the straddling method that is used to calibrate inductive voltage dividers (IVDs). A bridge of this type requires multiple, simultaneous balances, which, due to interactions between the various circuit networks involved, are difficult to achieve in practice. An algorithm will be demonstrated that achieves balances on the order of 1 part in 10^9.

BISHOP, Bradley E., Associate Professor and WICK, Carl E., Professor, "Educational Control Studies of a Differentially Driven Mobile Robot," *Proceedings of the 35th Southeastern Symposium on Systems Theory (SSST),* Morgantown, WV, March 2003, pp. 308-312.

In this paper, we discuss a set of experiments (both hardware and simulation-based) intended to reinforce the basic concepts of control of differentially-driven vehicles using dead reckoning.

DWAN, Terrence E., Professor and PIPER, George E., Associate Professor, "A Systems Engineering Approach to Energy Systems," *Proceedings of the 35th Southeastern Symposium on Systems Theory (SSST)*, Morgantown, WV, March 2003, pp. 322-325.

Environmental topics such as pollution prevention, pollution remediation, natural resource utilization, as well as global and local weather studies, provide an excellent catalyst for teaching engineering principles. For the past five years, the Systems Engineering and Ocean Engineering Departments at the U.S. Naval Academy have collaborated to offer an innovative two-course sequence in environmental engineering for non-environmental engineering students. The first course in this sequence is taught out of the Systems Engineering Department. This course covers a variety of engineering topics related to the environmental such as sensors, data collection, data processing, energy systems, and engineering economics. For the second course, students can choose from two more traditional environmental courses taught out of the Ocean Engineering Department. Topics include pollution prevention, pollution remediation, and natural resource utilization.

This paper describes the energy systems portion of this environmental engineering sequence. Energy is approached from the prospective of a systems engineer, who is concerned with the overall design of an energy system. Through novel laboratory exercises and projects, students become familiar with the various components of energy systems such as energy sources, conversion, storage, and utilization. They also get acquainted with sizing energy systems and the economics of energy.

ESPOSITO, Joel M., Assistant Professor, "Automated Test Trajectory Generation for Hybrid Systems," *Proceedings of the 35th Southeastern Symposium on Systems Theory (SSST)*, Morgantown, WV, March 2003, pp. 441-444.

This paper contains the first steps toward the development of an automated test-input generation algorithm -- inspired by test input generators for software systems -- for human-in-the-loop embedded systems such as automotive and avionic system as well as an increasing number of smaller consumer devices. 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 an 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 numerical optimal control based technique is presented. The tradeoff between computational cost and authenticity is explored.

Fang, Y., FEEMSTER, Matthew G., Assistant Professor, Dawson, D., and Jaili, N., "Nonlinear Control Techniques for the Atomic Force Microscope System," *Proceeding of the American Society of Mechanical Engineers (ASME) International Mechanical Engineering Congress and Exposition*, New Orleans, LA, November 2002, pp. 1-8.

This paper describes three nonlinear control techniques which are proposed for an atomic force microscope system. Initially, a learning-based control algorithm is developed for the microcantilever-sample system that achieves asymptotic cantilever tip tracking for periodic trajectories. Specifically, the hybrid control approach utilizes a combination of a learning-based feedforward term to compensate for periodic dynamics while high-gain terms are utilized to account for non-periodic dynamics. An adaptive control algorithm is then developed to achieve asymptotic cantilever tip tracking for bounded tip trajectories despite uncertainty throughout the system parameters. Lastly, a nonlinear controller coupled with a nonlinear observer is designed to provide for asymptotic tracking and interaction force identification under a set of assumptions.

Fang, Y, FEEMSTER, Matthew G., Assistant Professor, Dawson, D., and Jaili, N., "Active Interaction Force Identification for Atomic Force Microscope Applications," *Proceeding of the Institute for Electrical and Electronic Engineering (IEEE) Conference on Decision and Control*, Las Vegas, NV, December 2002, pp. 3678-3683.

In an effort to improve sub-molecular imaging precision, a general distributed-based modeling approach for the atomic force microscope system is proposed which allows for the design of a stabilizing controller/estimation scheme that stabilizes the micro-cantilever based system while asymptotically identifying the atomic interaction force. That is, the estimated interaction force asymptotically approaches the actual interaction force; hence, the estimated interaction force can be utilized to generate high precision atomic-resolution images. Differing from current practices of simple lumped model sets of ordinary differential equations, the proposed approach attacks the more difficult distributed parameter model.

HOBLET, Philip C., Midshipman 1/C, (USN), O'BRIEN Jr., Richard T., Associate Professor, and PIEPMEIER, Jenelle A., Assistant Professor, "Scale-Model Vehicle Analysis for the Design of a Steering Controller," *Proceedings of the 35th Southeastern Symposium on Systems Theory (SSST)*, Morgantown, WV, March 2003, pp. 201-205.

A scale-model vehicle was developed that is dynamically similar to a full-size vehicle through application of the Buckingham-PI theorem. Specifically, the vehicle is modified to match the corresponding Pi groups of the scale-model vehicle and the average of a number of full-size vehicles. The modifications require the mass of the vehicle and its distribution to be changed. Furthermore, an experimental apparatus was designed and built to measure the cornering stiffness of scale-model tires. Experimental data for the vehicle was compared to data for a number of full-size vehicles.

Kinarad, Joseph R., Lipe, Thomas E. and AVRAMOV-ZAMUROVIC, Svetlana, Associate Professor, "A New Binary Inductive Divider Comparator System for Measuring High-Voltage Thermal Converters," *Proceedings of the 2002 Institute for Electrical and Electronic Engineering (IEEE) Conference*, Vol. 51, No. 5, Vail, CO, October 2002, pp. 1045-1050.

National Measurement Institutes have traditionally used bootstrapping or build-up techniques to determine the ac-dc difference of high-voltage thermal (HVTCs) converters in terms of the ac-dc difference of lower-voltage converters. This paper describes a method of determining the ac-dc difference of HVTCs, which is independent of the build-up process. A description of the system and technique is given, and preliminary data presented.

O'BRIEN Jr., Richard T., Associate Professor, BOERNKE, Eric P., Midshipman 1/C (USN), and GORSKY, Lora M., Midshipman 1/C (USN), "Sampled-Data Control of Double Integrator Systems," *Proceedings of the 35th Southeastern Symposium on Systems Theory (SSST)*, Morgantown, WV, March 2003, pp. 413-416.

A sampled-data control system with bounded controls is introduced for double integrator systems. The control system uses samples of the output of a continuous-time, linear controller to determine the amplitude of a pre-determined, piecewise constant (bang-bang), control signal. The pre-determined control signal defines the inter-sample behavior of the system and generalizes the constant inter-sample behavior associated with a zero-order hold. Simulation results of the nominal and robust performance are presented.

O'BRIEN Jr., Richard T., Associate Professor, "On Teaching State-Space Control System Design Using A MATLAB Real-Time Experiment," *Proceedings of the 35th Southeastern Symposium on Systems Theory (SSST)*, Morgantown, WV, March 2003, pp. 317-321.

Topics in state-space control theory in a senior-level undergraduate course are introduced and investigated using the MATLAB real-time environment and an experimental apparatus. The experiment serves as a continuing application in the course. Specifically, the students explore two different design approaches and explore practical design issues such as unmodeled dynamics, control input usage and non-viscous friction.

O'BRIEN Jr., Richard T., Associate Professor, and WATKINS, John M., Associate Professor, "A Unified Approach For Teaching Root Locus And Bode Compensator Design," *Proceedings of American Control Conference*, Denver, CO, June 2003, pp. 645-649.

In an undergraduate controls course taught with a standard textbook, students often lose sight of the "forest" of control systems design because they struggle to master the numerous control system algorithm "trees" found in this textbook. As an alternative, the authors of this paper propose a design approach that is common for a large variety of compensators using both the more intuitive root locus design and the more practical Bode design methods. This approach is based on a simple procedure for root locus Proportional-Derivative (PD) design. In this paper, the Bode design procedures for three compensators: lead, PI, and Proportional-Integral-Derivative (PID) are developed from this simple PD design. Procedures for rate feedback, lag and PI-lead (practical PID) compensators have also been developed using this approach. The proposed Bode design procedures are very similar to the procedures developed for root locus design published previously. An example of a lead design from an undergraduate control system laboratory demonstrating this approach is presented.

PIEPMEIER, Jenelle A., Assistant Professor, KNOWLES, Kenneth A., Professor and BISHOP, Bradley E., Associate Professor, "Using MATLAB for Robotics Instruction," Proceedings of the 2002 American Society for Engineering Education (ASEE) Annual Conference and Exposition, Montreal, Quebec, June 2002. (CD-ROM)

An effective undergraduate robotics course will have strongly coupled laboratory and classroom components. It is important that the students experience the application of classroom theory. Often, this application is transparent when using the vendor supplied programming environments. For example, Cartesian move commands will move the robot to a desired point in the workspace without a need for explicit solution of the inverse kinematics problem by the student. Programming environments such as MATLAB, Maple, or C\C++ have long provided an ideal simulation environment for studying kinematic or dynamic robotic models. Environments such as MATLAB are especially ideal for engineering students with limited programming expertise. By taking advantage of the serial port capabilities in MATLAB's Release 12 and later versions, along with the ability to compile existing C\C++ code under the MATLAB shell, the instructor can devise assignments that allow the student to easily model and control robotic systems in the MATLAB environment. This paper discusses two approaches and representative laboratory assignments.

PIEPMEIER, Jenelle A., Assistant Professor, "Experimental Results for Uncalibrated Eye-in-Hand Visual Servoing," *Proceedings of the 35th Southeastern Symposium on Systems Theory (SSST)*, Morgantown, WV, March 2003, pp. 335-339.

This paper presents uncalibrated control schemes for vision-guided robotic tracking of a moving target using a

moving camera. These control methods were applied to an uncalibrated robotic system with eye-in-hand visual feedback. Without *a priori* knowledge of the robot's kinematic model or camera calibration, the system is able to track a moving object through a variety of motions and maintain the object's image features in a desired position in the image plane. These control schemes estimate the system Jacobian as well as changes in target features due to target motion. Four novel strategies were tested.

PIPER, George E., Associate Professor, WATKINS, John M., Associate Professor, Leitner, Jesse, and Markley, Landis, "On the Control Design of the Disturbance Reduction System for the LISA Mission," *Proceedings of the 2002 American Institute of Aeronautics and Astronautics (AIAA) Guidance, Navigation, and Control Conference*, Monterey, CA, August 2002 (CD-ROM)

The Laser Interferometer Space Antenna (LISA) mission will consist of a three spacecraft formation acting as a large interferometer. The spacecraft formation will measure the distortion of space caused by passing gravitational waves. Each spacecraft will contain two shielded proof masses that define the optical arms of the interferometer. To mitigate the effects of external disturbances, the LISA Disturbance Reduction System will control the spacecraft to fly drag-free trajectories with reference to their respective proof masses. This paper investigated control design issues associated with the LISA Disturbance Reduction System (DRS). In particular, this paper presented a 2 degrees-of-freedom (DOF) model representing a spacecraft with a single proof mass. With this model, key control design issues are identified. A Linear Quadratic Gaussian (LQG) controller design was presented to illustrate the feasibility of the DRS control concept. A 3 DOF model was used to explore the DRS implications of a spacecraft with two proof masses.

Stilwell, Daniel J. and BISHOP, Bradley E., Associate Professor, "Redundant Manipulator Techniques for Path Planning and Control of a Platoon of Autonomous Vehicles," Pro*ceedings of the 2002 Institute for Electrical and Electronics Engineering (IEEE) Conference on Decision and Control*, Las Vegas, NV, December 2002, pp. 2093 –2098.

An approach to real-time, decentralized trajectory generation for platoons of autonomous vehicles is developed from well-known control techniques for redundant robotic manipulators. The 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 is motivated by applications for which communications bandwidth is severely limited. The communication requirements for our decentralized trajectory generation approach are independent of the number of vehicles in the platoon. This permits control and path-planning of very large platoons despite limited communications bandwidth.

WATKINS, John M., Associate Professor and PIPER, George E., Associate Professor, "An Undergraduate Course in Active Magnetic Levitation: Bridging the Gap," *Proceedings of the 35th Southeastern Symposium on Systems Theory (SSST)*, Morgantown, WV, March 2003, pp. 313-316.

This paper described an undergraduate course in active magnetic levitation that was designed to engage the student's interest while bridging the gap between the mathematical and the physical world. The objective of this course was to take the students through the complete design process of a nontrivial control system prior to their capstone design course. The course focused on a project where the students modeled, analyzed, simulated, designed, and implemented, an active magnetic levitation control system. The paper discussed the pedagogical objectives of the course, an overview of the course, and highlights of several of the labs in the course.

WATKINS, John M., Associate Professor, PIPER, George E., Associate Professor and Leitner, Jesse, "Control of Time-Delayed Double Integrator Systems," *Proceedings of the American Control Conference*, Denver, CO, June 2003. (CD-ROM)

The control of system with large time-delays is a very challenging problem. As Proportional-Integral-Derivative (PID) controllers and variants of these such as P, PI, or PD are widely used in industry, there has been extensive work to determine the range of their gains that will stabilize a linear time-invariant plant described by a rational transfer function. However, the extension of this work to systems with time-delays has been difficult. In this paper,

the control of double integrators, a particular class of second-order systems, with time-delays will be considered. Double integrator systems are a simple, but important, class of second order systems, as they model single-degree of freedom translational and rotational systems. The study of time-delayed double integrator systems in this paper is motivated by the formation flying challenge. In this paper, the ability for tight formation control in the presence of communication and measurement delays is investigated. The paper begins with a discussion of the cross-link requirements for formation control. A simple two degree-of-freedom model with communication delays is introduced for analysis. A typical approach for systems with small time-delays is to base the design on a nominal system model that does not contain the time-delays. The limitations of this approach on stability and closed-loop bandwidth are discussed. The time-delay is explicitly considered in the design of state-feedback (PD) controllers. The effects of the time-delay on stability, stability margins, and closed-loop bandwidth were investigated.

ZIVI, Edwin L., Assistant Professor, and PIEPMEIER, Jenelle A., Assistant Professor, "The Implementation of a Classroom Laboratory Paradigm," *Proceedings of the 2002 American Society for Engineering Education (ASEE) Annual Conference and Exposition,* Montreal, Quebec, June 2002. (CD-ROM)

This paper describes a novel classroom design used in the Weapons and Systems Engineering Department at the United States Naval Academy to more strongly couple the classroom and laboratory experiences for undergraduate systems engineering students. The Weapons and Systems Engineering Department has replaced two roughly equally sized rooms dedicated separately as a laboratory and a classroom with one lab-classroom equal to roughly one and a half times the size of the pre-renovation rooms. Designed for roughly twenty students, the lab-classroom is designed to integrate course-specific engineering laboratory equipment with the traditional lecture environment. The coupling of the physical environments serves to blur the distinction between formerly disparate events including: lecture, computer modeling and simulation, and hardware implementation. Lab-classroom can be dedicated to specific disciplines within the major such as control systems, robotics, environmental engineering, communications, and microprocessors. In addition, our lab-classrooms are equipped with a variety of multimedia tools to facilitate student learning. For example, now one single room houses traditional desks, chalk boards, multimedia equipment, as well as ten robotic workstations including computers and vision systems. The paper discussed several of the lab-classroom activities that this new physical layout enables as well as faculty and student response.

ZIVI, Edwin L., Assistant Professor, "Design of Next Generation Warship Power and Automation Systems – The Challenges," *Proceedings of the 3rd Future Surface Warships Conference*, 23-24 September 2002, London, United Kingdom. (CD-ROM) (invited paper)

Future Navy surface combatants will be commissioned with significantly higher demands for electric power to support electric drive propulsion, high-energy weapon systems, electrical auxiliary systems, and network centric warfare. Electric warships enable flexible real-time power allocation, electric weapons, and advanced sensors providing a technically superior electric naval force. These interdependent and automated systems require dependable, integrated control to dynamically and efficiently manage limited resources. This requirement is critical during the major disruptions associated with battle and damage control operations. Existing naval combatants achieve mission availability through redundancy, isolation, and human intervention. Continuation of the traditional doctrine of physical and functional isolation of redundant systems imposes unacceptable cost, maintenance, and performance penalties for future electric warships. An Integrated Power System based on solid-state energy conversion, coupled with robust automation, provides the opportunity to integrate propulsion, ships service, and weapons power generation and distribution. The key enabler is the automation of the power system to achieve Integrated Fight Through Power. Specifically, disruptive events, including battle damage, must be detected and isolated before jeopardizing the overall system integrity. Implicit in this scenario is the transfer of damage control response from crewmembers to automation. Simultaneously, this transfer of responsibility is explicitly required to achieve "optimum" manning goals. The remaining obstacle involves engineering and fielding cost effective, survivable automation for a distributed and dynamically interdependent naval integrated power system.

ZIVI, Edwin L., Assistant Professor, "Integrated Shipboard Power and Automation Control Challenge Problem," *Proceedings of Institute for Electrical and Electronics Engineering (IEEE) Power Engineering Society Summer Meeting*, Chicago, IL, July 2002. (CD-ROM) (invited paper)

Control system requirements for highly automated and survivable future electric warships are presented herein to stimulate and unify interdisciplinary research conducted under the joint NSF/ONR Electric Power Networks Efficiency and Security (EPNES) initiative. This Office of Naval Research (ONR) challenge problem focuses on continuity of control for interdependent shipboard engineering and damage control systems under hostile conditions. The mission statement for these Hull, Mechanical, Electrical & Damage Control (HME&DC) systems may be summarized as: Provide continuous mobility, power, and thermal management for shipboard combat systems despite major disruptions involving cascading failures. This challenge problem is prototypical of analogous complex, interdependent systems including the national power grid, military and civilian infrastructure, and transport systems. These nonlinear, distributed, heterogeneous, variable structure systems contain dynamically interdependent subsystems. Mission/life critical system integrity and fault tolerance requirements demand dependable continuity of service. Innovative, dependable, and affordable control system architectures, strategies, algorithms, methods and tools are sought. After a brief problem statement and discussion of shipboard control systems, the ONR control challenge problem and reference system were presented.

ZIVI, Edwin L., Assistant Professor, Sudhoff, S. D., Pekarek, S. D., Glover, S. F., Żak, S. H., Sauer, J. D., and Delisle, D. E., "Stability Analysis of a DC Power Electronics Based Distribution System," *Proceedings of the SAE Power Systems Conference*, October 2002, Coral Springs, FL. (CD-ROM)

This paper illustrates the application of the generalized immittance space approach to the analysis of multi-bus interconnected power electronics based power distribution system. The paper sets forth the basic classifications of power converters in regard to stability analysis, a set of network reduction transformations, and illustrates the use of these reductions in order to analyze the stability of a zonal dc distribution system.

ZIVI, Edwin L., Assistant Professor, Glover, S. F., Żak, S. H., and Sudhoff, S. D., "Polytopic Modeling and Lyapunov Stability Analysis of Power Electronics Systems," *Proceedings of the SAE Power Systems Conference*, October 2002, Coral Springs, FL. (CD-ROM)

Power electronics based power distribution systems are inherently nonlinear often behaving as constant power loads. Stability analysis of such systems typically is limited to local behavior. Herein polytopic modeling techniques are presented. Classification of polytopic model equilibrium points is made and methods of determining uniform asymptotic stability are presented to evaluate the stability of a power electronics based source load system.

ZIVI, Edwin L., Assistant Professor, Sudhoff, S. D., Kuhn, B. T., Sauer, J. D., Delisle, D. E., and Clayton, D., "Impact of Pulsed Power Loads on Naval Power and Propulsion Systems," *Proceedings of the SAE Power Systems Conference*, October 2002, Coral Springs, FL. (CD-ROM)

In this paper, the impact of pulsed power loads on Naval power and propulsion systems is examined. The pulsed power load takes the form of a capacitor charging circuit which is periodically charged and nearly instantaneously discharged. Two basic configurations of pulsed power converters are considered; a load-commutated converter based charger, and an uncontrolled rectifier – dc/dc converter based charger. Each of these configurations was studied with and without the option of coordinating operation with propulsion.

ZIVI, Edwin L., Assistant Professor, Jatskevich, J., Lucas, C. E., Walters, E. A., and Wasynczuk, O., "Real-Time Distributed Simulation of DC Zonal Electrical Distribution System," *Proceedings of the SAE Power Systems Conference*, October 2002, Coral Springs, FL. (CD-ROM)

In this paper, a prototype DC Zonal Electrical Distribution System (ZEDS) developed under the Naval Combat Survivability effort is considered. A model of one zone is described in detail on a component level, and is viewed as a collection of interconnected dynamical subsystems each described by a set of state equations. An innovative approach for distributing the subsystems among multiple computers is shown to result in a significant improve-

ment in simulation speed. Moreover, when Average Value Models (AVMs) replace the detailed converter models, a faster than real-time simulation can be achieved.

ZIVI, Edwin L., Assistant Professor, Amy, J. V., and Whitcomb, C. A., "Naval Electric Power System Cost Objective Function," *Proceedings of the 13th International Ship Control Systems Symposium (SCSS2003)*, U.S. Navy, Naval Sea System Command, April 2003, Orlando, FL. (CD-ROM)

When considering alternative approaches in the design and operation of complex systems, objective functions enable assessments of the costs or utility of the alternatives. Further, the design and operation of controls for a complex system would endeavor to optimize, in some sense, the objective function chosen for that system. For example, commercial power systems seek to optimize a profit function for the given corporate agent. Hitherto, an objective function for naval electric power systems which control designers can employ has not been articulated. This may be due to the fact that the objective of naval electric power systems changes during operation. It may also be due to the fact that naval electric power systems are time-variant, nonlinear, dynamically complex and interdependent. Hence, this paper discusses necessary qualities of such an objective function which recognize the unique characteristics of naval electric power systems. It also treats an approach for accommodating the time-variant topologies and redundancies found in naval electric power systems. These discussions form the basis for defining an approach to realizing controls for naval electric power systems which optimize an objective function.

ZIVI, Edwin L., Assistant Professor, Pekarek, S. D., Tichenor, J., Sudhoff, S. D., Sauer, J. D., and Delisle, D. E., "Overview of a Naval Combat Survivability Program," *Proceedings of the 13th International Ship Control Systems Symposium (SCSS2003)*, U.S. Navy, Naval Sea System Command, April 2003, Orlando, FL. (CD-ROM)

Recently, the Energy Systems Analysis Consortium (ESAC), Naval Sea Systems Command (NAVSEA), and the Naval Surface Warfare Center (NSWC) have undertaken a major effort with regard to improving the survivability of electric warships. Research issues considered under this effort have included the development of advanced stability analysis tools, power converter control strategies, new time-domain simulation tools, improvement in multi-level power conversion and electric drive controls for electric propulsion systems, advanced methods of parameter identification, and investigations into the system effects of pulsed power loading. These investigations have centered around two laboratory scale test systems – the Naval Combat Survivability Generation and Propulsion Testbed, and the Naval Combat Survivability DC Distribution Testbed. In this paper, an overview of this program, including an introduction to the testbeds as well as a review of the principal research results obtained to date are set forth.

ZIVI, Edwin L., Assistant Professor, Sudhoff, S. D., Glover, S. F., Zak, S. H., Pekarek, S. D., Delisle, D.E., and Clayton, D., "Stability Analysis Methodologies for DC Power Distribution Systems," *Proceedings of the 13th International Ship Control Systems Symposium (SCSS2003)*, U.S. Navy, Naval Sea System Command, April 2003, Orlando, FL. (CD-ROM)

Power electronics based zonal dc power distribution systems are being considered for future Navy ships. The stability of dc power electronics based power distribution systems, and in particular dc systems, is a significant design consideration because of the potential for negative impedance induced instabilities. In this paper, methodologies for analyzing the stability of these systems are reviewed. In particular, tools including time-domain simulation, generalized immittance analysis, and polytopic analysis are considered. The use of both time-domain simulation and generalized immittance analysis for a three-zone hardware test system, the Naval Combat Survivability DC Distribution Testbed, is set forth. The predictions of both of these methods are shown to be in agreement with the observed behavior of the system. Polytopic analysis is then considered as a possible future tool for exploring stability properties. The results of each of these analyses as well as the respective advantages and disadvantages of each of the methods were compared.

ZIVI, Edwin L., Assistant Professor, and McCoy, T. J., "Office of Naval Research (ONR) Ship Control Challenge Problem," *Proceedings of the 13th International Ship Control Systems Symposium (SCSS2003)*, U.S. Navy, Naval Sea System Command,

April 2003, Orlando, FL. (CD-ROM)

The Office of Naval Research (ONR) and the National Science Foundation (NSF) have embarked on a collaborative initiative to achieve Electric Power Network Efficiency and Security (EPNES) [1-3]. This paper presents the U. S. Navy research objectives in terms of an ONR control challenge problem. From a shipboard operational perspective the challenge can be stated as: Provide continuous mobility, power, and thermal management for shipboard combat systems despite major disruptions involving cascading failures. A key aspect of this problem involves controlling the dynamic interdependence of a hierarchically structured distributed power and automation infrastructure. A reference problem is posed in terms of continuity of service for a prototypical future power electronics based shipboard Integrated Power System (IPS). The goal is to incorporate fault tolerance and system integrity as an organic component of the system architecture, control strategy, algorithms, and technology base. Innovative research that directly contributes to a more robust automation infrastructure is required. Conceptually, the control system equivalent of an error correcting code is sought [4]. The desired system must maintain situational awareness and control authority despite a variety of component failures, internal errors, and exogenous disturbances.

ZIVI, Edwin, Assistant Professor, Sudhoff, S. D., Kuhn, B. T., Delisle, D.E., and Clayton, D., "Impact of Pulsed Power Loads on Naval Power and Propulsion Systems," *Proceedings of the 13th International Ship Control Systems Symposium (SCSS2003), U.S. Navy, Naval Sea Systems Command,* April 2003, Orlando, FL. (CD-ROM)

In this paper, the impact of pulsed power loads on naval power and propulsion systems is examined. The pulsed power load takes the form of a capacitor charging circuit, which charges an energy storage capacitor. The capacitor is then nearly instantaneously discharged and the cycle can then be repeated. Two basic configurations of pulsed power charging circuits are considered; a load-commutated converter based charger and an uncontrolled rectifier – dc/dc converter based charger. Each of these configurations was studied with and without the option of coordinating operation with propulsion to potentially reduce system impact.

ZIVI, Edwin L., Assistant Professor, Lucas, C. E., Walters, E. A., Jatskevich, J., and Wasynczuk, O., "Distributed Heterogeneous Simulation of Large-Scale Dynamical Systems," *Proceedings of the 13th International Ship Control Systems Symposium (SCSS2003)*, U.S. Navy, Naval Sea Systems Command, April 2003, Orlando, FL. (CD-ROM)

In this paper, a new technique useful for the numerical simulation of large-scale systems is presented. This approach enables the overall system simulation to be formed by the dynamic interconnection of the various interdependent simulations, each representing a specific component or subsystem such as control, electrical, mechanical, hydraulic, or thermal. Each simulation may be developed separately using possibly different commercial-off-the-shelf simulation programs thereby allowing the most suitable language or tool to be used based on the design/analysis needs. For the purpose of demonstration, this technique is applied to a detailed simulation of a representative naval aircraft power system, such as that found on the Joint Strike Fighter (JSF). This system is comprised of ten component models each developed using MATLAB/Simulink™, EASY5™, or ACSL™. When the ten component simulations were distributed across just four personal computers (PCs), a greater than 15-fold improvement in simulation speed (compared to the single-computer implementation) was achieved.

Book Review

BISHOP, Bradley E., Associate Professor, "Behavior-Based Robotics by Ronald C. Arkin – A Review," *Automatica*, Vol. 38 No. 12, pp. 2191 – 2196, December 2002.

This invited book review discusses the fundamental connection between control theory and the field of behavior-based robotics through an analysis of the seminal textbook in the field of reactive robotic systems.

Other

ESPOSITO, Joel M., Assistant Professor, "Simulation and Control of Hybrid Systems with Applications to Mobile Robotics," University of Pennsylvania, PhD Thesis, December 2002.

> As microprocessors become cheaper, more powerful, smaller and more pervasive, many physical systems must now be modeled as a mixture of continuous dynamics and discrete logic systems. Such systems are modeled as hierarchical hybrid systems (HHS). In the first p[art of this thesis three novel numerical simulation methods for HHS are introduced. The first represents the only known algorithm which is capable of detecting and localizing discrete transitions in close proximity to model singularities. The second algorithm is multi-rate numerical integration scheme for HHS. The third algorithm is concerned with simulating many such systems simultaneously. The last two algorithms place a high premium on efficiency.
>
> The second part of this thesis a framework for reactive motion planning and control of mobile robots is introduced. We assume a suite of low level controllers has been designed, the problem then is how to compose these control laws either by designing a switching sequence (sequential composition) or designing and entirely new control modes (parallel composition), in such a way that the aggregate behavior of the system achieves all of the objectives simultaneously, or reports failure if it is impossible to do so. The resulting control algorithm is a hierarchical hybrid system.

Presentations

AVRAMOV-ZAMUROVIC, Svetlana, Associate Professor, Waltrip, Bryan, Koffman, Andrew and PIPER, George E., Associate Professor, "Straightforward Design of Accurate Inductive Voltage Dividers," American Society for Engineering Education (ASEE) Conference, Montreal, Quebec, June 2002.

AVRAMOV-ZAMUROVIC, Svetlana, Associate Professor, Waltrip, Bryan, Stricklett, Ken and Koffman, Andrew, "Balancing Procedure for an IVD Bridge," Instrumentation and Measurement Technology (IMTC) Conference 2003, Vail, CO, May 2003.

BISHOP, Bradley E., Associate Professor and WICK, Carl E., Professor, "Educational Control Studies of a Differentially Driven Mobile Robot," 35th Southeastern Symposium on Systems Theory (SSST), Morgantown, WV, March 2003.

DWAN, Terrence E., Professor and PIPER, George E., Associate Professor, "A Systems Engineering Approach to Energy Systems," 35th Southeastern Symposium on Systems Theory (SSST), Morgantown, WV, March 2003.

ESPOSITO, Joel M., Assistant Professor, "Automated Test Trajectory Generation for Hybrid Systems," 35th Southeastern Symposium on Systems Theory (SSST), Morgantown, WV, March 2003.

KIRIAKIDIS, Kiriakos, Associate Professor, "Community Robotics," 35th Southeastern Symposium on Systems Theory (SSST), Morgantown, WV, March 2003.

KIRIAKIDIS, Kiriakos, Associate Professor, "Formal Modeling and Supervisory Control of Reconfigurable Robot Teams," NASA/Goddard Workshop on Formal Approaches to Agent-Based Systems, Greenbelt, MD, October 2002.

KIRIAKIDIS, Kiriakos, Associate Professor, "Extended H-infinity Filtering to Determine Direction of Arrival (DOA)," SIAM 50th Anniversary and Annual Meeting, Philadelphia, PA, July 2002.

PIEPMEIER, Jenelle A., Assistant Professor, KNOWLES, Kenneth A., Professor and BISHOP, Bradley E., Associate Professor, "The Use of MATLAB for Robotic Control in an Undergraduate Robotics Laboratory," 2002 American Society for Engineering Education (ASEE) Annual Conference and Exposition, 1520 Computers in Education Poster Session, Montreal, Quebec, June 2002.

PIEPMEIER, Jenelle A., Assistant Professor, KNOWLES, Kenneth A., Professor and BISHOP, Bradley E., Associate Professor, "Using MATLAB for Robotics Instruction," 2002 American Society for Engineering Education (ASEE) Annual Conference and Exposition, Montreal, Quebec, June 2002.

O'BRIEN Jr., Richard T., Associate Professor, "Academic Assessment at the United States Naval Academy," Accreditation and Quality Assurance Conference, Washington, DC, December 2002.

O'BRIEN Jr., Richard T., Associate Professor, "On Teaching State-Space Control System Design Using a MATLAB Real-Time Experiment," 35th Southeastern Symposium on Systems Theory (SSST), Morgantown, WV, March. 2003.

O'BRIEN Jr., Richard T., Associate Professor, "Single Snapshot Robust Direction Finding," Office of Naval Research (ONR) Review, Arlington, VA, March 2003.

O'BRIEN Jr., Richard T., Associate Professor, "A Unified Approach For Teaching Root Locus and Bode Compensator Design," American Control Conference, Denver, CO, June 2003.

PIPER, George E., Associate Professor, and WATKINS, John M., Associate Professor, "On the Control Design of the Disturbance Reduction System for the LISA Mission," 2002 American Institute of Aeronautics and Astronautics (AIAA) Guidance, Navigation, and Control Conference, Monterey, CA, August 2002.

PIPER, George E., Associate Professor, "A Systems Engineering Approach To Teaching Energy," 35th Southeastern Symposium on Systems Theory (SSST), Morgantown, WV, March 2003.

PIPER, George E., Associate Professor, "Active Sound Control," Naval Research Laboratory, Washington, DC, April 2003.

Stilwell, Daniel J., and BISHOP, Bradley E., Associate Professor, "Redundant Manipulator Techniques for Path Planning and Control of a Platoon of Autonomous Vehicles," 2002 Institute for Electrical and Electronic Engineering (IEEE) Conference on Decision and Control, Las Vegas, NV, December 2002.

WATKINS, John M., Associate Professor and PIPER, George E., Associate Professor, "An Undergraduate Course in Active Magnetic Levitation: Bridging the Gap," 35th Southeastern Symposium on Systems Theory (SSST), Morgantown, WV, March 2003.

ZIVI, Edwin L., Assistant Professor, "Design of Next Generation Warship Power and Automation Systems – The Challenges," Proceedings of the 3rd Future Surface Warships Conference, London, United Kingdom, September 2002.

ZIVI, Edwin L., Assistant Professor, "ONR Control Challenge Problem," Office of Naval Research (ONR) Control Challenge Kickoff Meeting, U. S. Naval Academy, Annapolis, MD, November 2002.

ZIVI, Edwin L., Assistant Professor, "ONR Control Challenge: NNR & CAPS Team," Presented at the U. S. Naval Academy, Annapolis MD, November 2002 to RADM Jay M. Cohen, Chief of Naval Research (CNR).

ZIVI, Edwin L., Assistant Professor, "Power and Automation Challenges for an Electric Naval Force," Center for Advanced Power Systems Meeting at Florida State University, Tallahassee, FL, December 2002.

ZIVI, Edwin L., Assistant Professor, "Systems Engineering and Automation Task," Office of Naval Research (ONR) National Naval Responsibility (NNR) Electric Ship Integration Initiative (ESI) Kickoff Meeting, Massachusetts Institute of Technology, Boston, MA, January 2003.

ZIVI, Edwin L., Assistant Professor, "Distributed Heterogeneous Simulation of Large-Scale Dynamical Systems," 13th International Ship Control Systems Symposium (SCSS2003), U.S. Navy, Naval Sea System Command, Orlando, FL, April 2003.