Weapons and Systems Engineering Department

Professor Terrance 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 that 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 fuzzy modeling, magnetic bearings, metrology, robotics, ship power systems, and system identification.

This year there were two Trident Scholars in the Systems Engineering Department. The scholars engage in extensive research projects in lieu of several courses. The research first topic was a development of a three dimensional vision system and the second scholar addressed shipboard automation.

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, magnetic levitation, and vibration control.

Funding for research continues to be diverse. This year sponsors included the Naval Academy Research Council, the Office of Naval Research, the Naval Research Laboratory, the Naval Surface Warfare Center, and the National Institute of Standards and Technology.

Sponsored Research

Hybrid System Theory for Vision-Driven Robotic Systems

RESEARCHER: Assistant Professor Bradley E. Bishop
SPONSORS: Naval Academy Research Council (NARC) and Office of Naval Research (ONR)

The use of computer vision in robotic applications is strongly motivated by the primacy of vision among human senses used for planning and executing manipulation tasks. While a great deal of effort has been devoted to development of exceptionally sophisticated visual processing techniques, surprisingly few researchers have approached the problem from a standpoint of sensing for real-time closed-loop control.

This project is aimed at utilizing the fundamental nature of a digital computer vision system in concert with closed-loop control for improvement of flexibility and performance of robotic systems in dynamic and uncertain environments. The primary tool used in these investigations is to be hybrid system theory (HST), in which various controllers and sensing strategies are implemented at various times in order to optimize the performance of the system based on objectives, world and system state and knowledge of the dynamics of control and vision.

This project is an extension of my work on visual servo using HST. Previous results indicate that careful system analysis must be carried out in order to achieve desired performance, especially when using nonlinear controllers whose properties are primarily local in nature. The goal of the research is to develop fundamental synthesis techniques for suites of visual processing strategies as well as full system synthesis techniques relating hybrid control to hybrid sensing for uncertain and rapidly changing

environments. As an initial step, investigations into the fundamental nature of nonlinear hybrid systems are being carried out in order to develop potential synthesis techniques that are applicable to the visually-driven robotics problem.

Supervisors for Adaptive Systems

RESEARCHER: Assistant Professor Kiriakos Kiriakidis
SPONSOR: Naval Research Laboratory (NRL)

The objective of the work is to synthesize adaptive systems that behave according to a desirable language. First, we approach the problem using the framework of supervisory control theory. In this sense, we separate the system in one part, known as the plant, that comprises all subsystems and their individual events, and another part, the supervisor, that enables or disables controllable events. Second, we develop a technique that handles the case where one or more subsystems fail. In brief, this technique removes from the desirable language all events associated with those subsystems and, by regrouping the remainder of events, completes a new desirable language that maintains certain properties that the system had before failure occurred. Third, we synthesize a new supervisor that guarantees that the closed-loop system (i.e., plant and supervisor) executes the new desirable language. Finally, we apply the above method to a three-agent model of the data collection and communication system of the Pathfinder mission to Mars. This project is complete.

Supervisory Control of Learning Multi-agent Systems

RESEARCHER: Assistant Professor Kiriakos Kiriakidis
SPONSOR: Naval Research Laboratory (NRL)

Multi-agent architectures are characteristic of composite systems such as a platoon of mini-submersibles or a swarm of micro-air-vehicles. Because the behavioral complexity of multi-agent systems increases with the number of agents, ad hoc solutions that work for groups of few agents are difficult to generalize for large-scale architectures. For systems with fixed structure, the methodology of supervisory control successfully treats the analysis and design of the agents' collective behavior. A more challenging problem, however, arises when the structure of a multi-agent system changes, for example, through learning. Herein, we develop an approach that extends the supervisory control theory to learning multi-agent systems and guarantees the collective behavior within specifications in spite of structural changes. This project is in progress.

H-infinity Active Noise Control of Fan Noise in an Acoustic Duct

RESEARCHERS: Assistant Professor Richard T. O'Brien, Jr., Assistant Professor John M. Watkins, Associate Professor George E. Piper and David C. Bauman (NSWC)
SPONSOR: Naval Surface Warfare Center B, Annapolis Detachment

Active control of noise in ducts has been an area of continuing research in the signal processing and the automatic control communities. The objective of active noise control (ANC) is to reduce the noise from a disturbance source by transmitting sound from a secondary (anti-noise) source. A critical limitation of ANC is that noise reduction can be achieved only at certain locations unless the anti-noise source and the disturbance noise source are co-located.

One of the principal sources of noise in a duct system is a fan or blower. Previous investigations of active control of fan noise have focused on tonal noise reduction. In this case, magnetic bearings were used to support an axial fan and, in addition, to vibrate the fan. The vibrated fan acts as an anti-noise source. In the context of ANC, the advantages of magnetic bearings are that no external actuator hardware is required and that the disturbance and anti-noise sources are co-located.

In previous work, the authors have investigated the use of magnetic bearings to achieve broadband and tonal noise reduction at all points along the duct. In this project, several important implementation issues are incorporated into the design of an H-infinity active noise controller. The acoustics of the duct are described by an infinite dimensional model due to transport delays. The controller design is based on a state space model identified from the infinite dimensional model using recently develop subspace identification techniques. In previous work, the effect of the transport delays was neglected. Furthermore, the

active noise controller is implemented in the simulation as a discrete-time controller by sampling the continuous-time H-infinity controller. Finally, the order of H-infinity controller is significantly reduced by eliminating pole/zero cancellations and performing model reduction on a balanced realization of the controller.

The results of the project are promising for physical implementation. As expected, the transport delays limit the range of noise frequencies that can be attenuated. Within this range, significant attenuation can be achieved. Also, the discrete-time controller performs as well as the continuous-time controller for a reasonable sampling rate (2kHz). Finally, the performance is unchanged after model reduction that reduced the controller from 44 states to 16 states.

Autonomous Spacecraft Rendezvous and Capture

RESEARCHER: Associate Professor George E. Piper
SPONSOR: Naval Research Laboratory (NRL)

The Spacecraft Engineering Department at Naval Research Laboratory is developing a Dynamic Motion Simulator for Space Robotics Experiments. The project=s objectives are to establish a state-of-the-art test facility for the evaluation of control system sensors, actuators, and logic designed to perform autonomous rendezvous, capture, servicing, or assembly operations in space. The simulator will consist of two full scale robotic vehicles and a simulation processor. One robotic vehicle will act as a chase spacecraft and the other robotic vehicle to act as a target spacecraft. The simulation processor computes the dynamic behavior of the spacecraft in real time as they perform maneuvers in space. In conjunction, the simulation processor will command the robotic vehicles to move in accordance with the simulated spacecraft behavior.

The objective for this year was to support the design of NRL's Dynamic Motion Simulator. My specific role in the simulator's design was to develop the real-time simulation software for the simulation processor. During the year, I supported two design reviews at NRL in which I helped define the simulator's control architecture and subsystems. I also developed simulation software for spacecraft rendezvous and capture that will be incorporated into the Dynamic Motion Simulator.

A Framework for Assessing Minimum Communication Requirements for Cooperating Underwater Weapons and Vehicles

RESEARCHERS: Assistant Professor Daniel J. Stilwell and
Assistant Professor Bradley E. Bishop
SPONSOR: Office of Naval Research

Limited communications bandwidth is a significant obstacle for decentralized control and coordination of underwater weapons and vehicles, including networks of torpedoes, anti-torpedo torpedoes and autonomous underwater vehicles (AUVs). The goal of this research is to characterize *minimum* inter-vehicle communication requirements using a systems-theoretic framework for tasks including formation control, distributed sensing, and distributed navigation.

Development of a Miniature Automonous Underwater Vehicle and Evaluation of Autopilot/Guidance Systems

RESEARCHERS: Associate Professor Carl E. Wick and Assistant Professor Daniel J. Stilwell
SPONSOR: Northrop Grumman Oceanic Systems

For this project, construction of a miniature autonomous (approx. 10 x 60 cm) underwater vehicle will be finalized and initial in-water testing will determine vehicle dynamics for refining mathematical models of motion and for the development of basic stabilization algorithms. Techniques for an advanced autopilot and guidance system will be studied. Performance measures for basic platform stabilization and for advanced autopilot/guidance systems during the period of this work will be navigation error along a straight-line path. Two classes of autopilot/guidance systems will be studied. The first utilizes a standard single-loop autopilot and Kalman filter guidance system. The second is a tightly coupled autopilot/guidance system that is designed using modern robust control techniques. Design of the latter autopilot/guidance system will require detailed modeling of the AUV dynamics.

Magnetic Suspension of an Optical Chopper Mechanism for the High Resolution Dynamics Limb Sounder (HIRDLS) Project

RESEARCHERS: Assistant Professor John M. Watkins, (USNA),
Mr. Kenneth Lee, Mr. Carlos Hernandez, Mr. Kenneth Blumenstock and Mr. Joseph Schepis,
Electromechanical Systems Branch
SPONSOR: NASA/Goddard Space Flight Center

HIRDLS is an infrared limb-scanning radiometer designed to fly on the Earth Observing System-Chemistry satellite and to measure the temperature, the concentrations of certain gasses, and the location of clouds in the upper atmosphere. An integral component of HIRDLS is an optical chopper designed to operate at 5000-200 rpm for five years in outer space. Ground testing of the ball bearings in the optical chopper has indicated potential failure of the bearings after three years. The goal of this research was to investigate the feasibility of replacing the ball bearings with magnetic bearings. Magnetic bearings magnetically suspend the optical chopper. This eliminates the friction between the bearings and the rotor and consequently eliminates the potential failures present with standard bearings. In this work, we were able to develop an adaptive auto-balancing control scheme that suspended the bearings and adaptively eliminated excessive wobble due to mechanical imbalances.

Yard Patrol Craft Automation Demonstration

RESEARCHER: Assistant Professor Edwin L. Zivi
SPONSOR: Office of Naval Research (ONR)

The Naval Research Advisory Committee has called for robust demonstrations of automation for reduced manning. In response, YP-679 has been transferred from USNA to ONR ownership as a dedicated automation technology demonstration platform. USNA has teamed with Florida Atlantic University, Adept Systems, Vector Research, and the Carderock Division of the Naval Surface Warfare Center, to perform a YP-679 automation demonstration under ONR funding of $1.5M. Initial demonstrations, to be performed summer of 2000, involve automation of propulsion, propulsion ancillaries, and steering. This control system upgrade will demonstrate the feasibility of using commercial, component level, intelligent control, for critical shipboard machinery systems. Florida Atlantic University and Adept Systems have extended Lon Works based, distributed, control technology to include network fragment healing. Network fragment healing transparently replaces single-points-of-failure with redundant sentinels and routers to reconfigure around battle damage. USNA is providing technical coordination and researching the extension of network fragment healing to complex/interactive systems.

Independent Research

On the Steering of an Articulated Vehicle Using Differential Braking

RESEARCHERS: Assistant Professor Richard T. O'Brien, Jr. and Associate Professor George E. Piper

The need to accommodate increased vehicular traffic on existing highways has motivated research into intelligent transportation systems. In particular, automated highway systems (AHS) have been proposed as an alternative to the construction of new highways. Primarily, AHS research has focused on the automation of passenger vehicles. More recently, automated steering control for articulated vehicles (i.e., tractor-trailers) has been examined. The benefits of these systems would be safer, less congested highways. The drawback is that an extensive infrastructure is required to implement such a system.

In the absence of AHS, individual vehicle automation items such as speed-sensitive steering, traction control, tire pressure monitoring systems, and "sensor-based virtual bumpers" have been developed to enhance the driver's ability to control the vehicle. These improvements are localized to the vehicle and do not require the infrastructure of AHS. The aim of this project is to investigate localized automation for articulated vehicles.

In this project, the design of a steering controller for the trailer of an articulated vehicle using differential braking is investigated. The control objective is to regulate the relative angle between the tractor and trailer to a desired angle determined by the road curvature and speed of the vehicle. A dynamic model of the vehicle has been developed and linearized for a constant velocity and zero relative angle condition. A preliminary feasibility study of this linear model demonstrated that this relative angle is controllable from a differential braking force applied at the trailer tires. Furthermore, the relative angle is observable from the output assuming that the vehicle's lateral position can be measured. Several options for measuring the lateral position without the use of AHS infrastructure as discussed. A steering controller is designed using a H-infinity design procedure because H-infinity controllers exhibit robustness to unmodeled dynamics and model uncertainty. Simulation results are provided to demonstrated the controller's effectiveness.

Research Course Projects

Neural Network Fault Tolerant Control of an Integrated Power System

RESEARCHER: Midshipman 1/C Jonathan J. Cerrito, USN
ADVISER: Assistant Professor Edwin L. Zivi
SPONSOR: Trident Scholar Program

Neural networks are investigated for fault tolerant stabilization and control of an Integrated Power System (IPS). Neural networks can be robust in the sense that they are not disabled by incomplete or inconsistent information. As non-model based observers, neural networks are ideally suited to estimation of complex, interactive power systems. Specifically, the ability of neural networks to adapt to uncertain eventualities such as flooding, fire, and combat casualties is investigated. The IPS under consideration will provide integrated propulsion and ship's service power generation and distribution for the next generation of U.S. Navy surface ships also known as the DD-21. These solid state power systems involve nonlinear dynamics which can lead to "negative impedance" instability and voltage collapse. Feedforward back-propagating neural networks were evaluated with respect to variable structure and data degradation. This research represents an initial step toward unifying nonlinear, negative impedance stabilization with robust neural network fault detection and isolation. The Naval Sea Systems, Integrated Power System and the Office of Naval Research, Electrically Reconfigurable Ship programs motivated this research.

Yard Patrol Craft Graphical Watchstation

RESEARCHERS: Midshipman 1/C Nathan K. Mote and Midshipman 1/C Joel A. Hartel, USN
ADVISER: Assistant Professor Edwin L. Zivi
SPONSOR: Office of Naval Research (ONR)

This ES495/ES496/ES402 midshipman research project was performed in support of the ONR 334 YP-679 automation demonstration program. Specifically, this project developed single computer watchstation with a graphical human/machine interface (HMI) for control of propulsion plant, electric plant, bridge, and fluid management systems onboard YP-679. In addition, this HMI was designed to interact with an autopilot system developed by Midshipman 1/C Joel Hartel. Finally, the HMI was extended to include a preliminary network status display page. The ultimate goal of this project was to minimize watchstations and manning requirements by creating an HMI that collected and displayed data in a user-friendly format.

After a detailed investigation of available display technology, AIMAX commercial HMI software was chosen for graphical user interface development. AIMAX was chosen because it supports the LonWorks distributed network communication protocols used in the YP-679 automation demonstration. Windows/NT workstations were selected for both software development and installation on YP-679. Display pages were designed via statecharts[1] and implemented using the AIMAX graphics builder. Integration of AIMAX and LonWorks software was performed in cooperation with the Naval Surface Warfare Center, Philadelphia. Under ONR sponsorship, NSWC produced a small scale LonWorks demonstration network to support the midshipman project.

Yard Patrol Craft Autopilot

RESEARCHER: Midshipman 1/C Joel A. Hartel, USN
ADVISER: Assistant Professor Edwin L. Zivi
SPONSOR: Office of Naval Research (ONR)

This ES495/ES402 midshipman research project was performed in support of the ONR 334 YP-679 automation demonstration program. Specifically, this project strove to develop an autopilot which took advantage of the LonWorks distributed automation to be demonstrated on YP-679. The ultimate goal of this project was to minimize manning requirements by integrating autopilot functions with a companion graphical computer watchstation.

Computer workstation and distributed microprocessor system configurations were considered during the autopilot system design. With support from the Naval Surface Warfare Center, Philadelphia, an interface with LonWorks control network was established. Interfaces to the Mark 27 MOD1 gyrocompass, Differential GPS, Knot Meter, and Depth Sounder were designed but not implemented due to time and funding constraints. A software autopilot implementation was demonstrated on a Windows/NT workstation. Final hardware integration awaits future midshipman senior design projects.

Multiple Aperture Camera System

RESEARCHER: Midshipman 1/C John P. Stevenson, USN
ADVISER: Associate Professor Carl E. Wick
SPONSOR: Trident Scholar Program

This project investigated the process of transforming wide angle images from multiple fixed tv cameras into a single, non-distorted image that could be oriented in any direction by computer manipulation alone. The Trident Project was completed satisfactorily and was presented to the faculty and students in April 2000.

Design Course Projects

Each Systems Engineering major enrolls in ES402, Systems Engineering Design, during senior year. This course is the capstone of the Systems Engineering curriculum. The student is required to propose, design, construct, test, and demonstrate and evaluate a system of particular personal or general professional interest.

The ES402 design course requires the combined effort of the total Systems Engineering Department faculty. Military instructors normally function as project monitors and help with organization, administration, and scheduling of individual projects. Civilian faculty function as technical advisors, and military and civilian technicians supply the hands-on technical help. The results of academic year 1999-2000:

Cocktails and Dreams
Midshipmen 1/C Jeremy P. Adams, Aaron J. Running and Joseph A. Pommerer, USN
Adviser: Lieutenant Commander Kenneth L. McElroy, USN

Solar Powered Board
Midshipmen 1/C Phillip C. Aramburu, Ramona J. Bagwell and John R. Duarte, USN
Adviser: Commander John J. Viniotis, USN

Maze of Doom
Midshipmen 1/C John R. Augenblick and Daniel P. Delacruz, USN
Adviser: Commander Juan A. Navarrete, USN

Maze of Doom
Midshipmen 1/C Jonathan E. Beard, Nathan J. Gammache and Timothy J. Myers, USN
Adviser: Commander Jay A. Gutzler, USNR

Walking Robot
Midshipmen 1/C Christina T. Beaty, Lennard D. Cannon, Ricardo J. Rodriguez, Guillermo F. Von Breymann, David M. Wolfe and Colin R. Young, USN
Adviser: Lieutenant George D. Doney, USN

Simulated Helo
Midshipmen 1/C Jennifer M. Becht and Michael S. Beaty, USN
Adviser: Commander John F. McKernan, USN

The Octopus
Midshipmen 1/C Joseph P. Bobrowski and Stephen R. Stage, USN
Adviser: Commander Jay A. Gutzler, USNR

Water Treatment System
Midshipmen 1/C Robert H. Burns and Christopher H. Lankford, USN
Adviser: Lieutenant Commander Brian S. Tait, USN

Crisis Early Warning System
Midshipman 1/C Michael J. Cernuska, USN
Adviser: Commander Joseph B. Hall, USN

Fire Fighting Robot
Midshipmen 1/C Adnen Chaabane and Yanko K. Videv, USN
Adviser: Commander Bradley D. Taylor, USNR

Mobile Robot
Midshipmen 1/C Kevin A. Chalan, Michael J. Coffeey, Patrick W. Sundy and John D. Wray, USN
Adviser: Commander Frederick A. Hoover, USNR

The Perfect Spot
Midshipman 1/C Andrew J. Conner, USN
Adviser: Lieutenant Commander Frederic D. Forney, USN

Designated Driver
Midshipmen 1/C Shawn E. Conniff and Erik M. Thomas, USN
Adviser: Lieutenant Colonel William W. Arrasmith, USAF

Voice-Activated Bartender Caddie
Midshipmen 1/C Donald H. Costello and Stephen J. Hershman, USN
Adviser: Commander David T. Bailey, USN

Automated Warehouse
Midshipmen 1/C Jonathan A. Crawford and Jon M. Gagnon, USN
Adviser: Commander Frederick A. Hoover, USNR

Tracked All Terrain Vehicle
Midshipmen 1/C Jeremy R. Czeschin, Daniel R. Nolan and Charles R. Robbins, USN
Adviser: Lieutenant Commander Franklin D. Hixenbaugh, USN

Auto Blackjack
Midshipmen 1/C David G. Davis and Peter A. Morgan, USN
Adviser: Major Thomas L. Langlois, USMC

Rough Rider All Terrain Vehicle
Midshipmen 1/C Jason W. DeBlock and Benjamin T. Huggins, USN
Adviser: Lieutenant Commander Brian S. Tait, USN

Hot Circle Plinker
Midshipman 1/C Patrick S. Dennis, USN
Adviser: Commander David T. Bailey, USN

Baby Penguin
Midshipmen 1/C John R. Elliott, John C. King, Robert N. Stonaker and Kevin J. Szepe, USN
Adviser: Commander Joseph B. Hall, USN

Foosball Table
Midshipmen 1/C Ryan C. Fair, Maurice K. Karagiorgos and Eric C. Thompson, USN
Adviser: Commander Rodney M. Adams, USNR

Autonomous Underwater Vehicle
Midshipmen 1/C Zachary R. Farrar, Matthew S. Janczak, Christopher L. Larson,
Juan A. Luna, Marc M. Morhack, Michael P. Slavik and Kelly D. Taylor, USN
Adviser: Lieutenant Commander Franklin D. Hixenbaugh, USN

Solar Powered Boat
Midshipmen 1/C James M. Farrow, Andrew P. Pearson and John L. Randazzo, USN
Adviser: Commander Juan A. Navarrete, USN

Self-Tuning Guitar
Midshipman 1/C Brian K. Galloway, USN
Adviser: Lieutenant Colonel William W. Arrasmith, USAF

Nacmar Beam Robot
Midshipmen 1/C John T. Gonser, Jason W. Israel and Jedd C. Mosher, USN
Adviser: Commander Bradley D. Taylor, USNR

Autonomous Underwater Vehicle
Midshipmen 1/C Jeff D. Groves, Kathryn E. Hendel and Matthew D. Obrian, USN
Adviser: Lieutenant Commander Brent A. Ditzler, USN

Automated Fishing Pole
Midshipmen 1/C Jason A. Gustafson and Robert J. Perez, USN
Adviser: Commander John F. McKernan, USN

Computerized YP Control
Midshipman 1/C Joel A. Hartel, USN
Adviser: Lieutenant Commander Kenneth L. McElroy, USN

Hovercraft
Midshipmen 1/C Damon V. Hildebrand, Christopher J. Roscetti and Jeremy A. Shamblee, USN
Adviser: Commander John J. Viniotis, USN

Solar Powered Boat
Midshipmen 1/C Stephone C. Hines, Sarah C. Maas, Lael H. Matthews and William K. McKinney, USN
Adviser: Lieutenant Commander Frederic D. Forney, USN

Crab Trap 2000
Midshipmen 1/C Adam R. Horn and Drew J. Irvin, USN
Adviser: Lieutenant Commander Kenneth L. McElroy, USN

Walking Robot
Midshipmen 1/C Blake W. Jackson and Michael B. Slatt, USN
Adviser: Lieutenant George D. Doney, USN

Bomb Disposal Robot
Midshipmen 1/C Charles A. Jindrich and Brett M. McDaniel, USN
Adviser: Commander Joseph B. Hall, USN

Maze of Doom
Midshipmen 1/C Nicholas M. Kalt, Erik J. Kjellgren, Roy J. Nicka and Kyle B. Shoop, USN
Adviser: Lieutenant Commander Brian S. Tait, USN

Laser Comms and Tracking
Midshipmen 1/C Larry M. Kane and Joel C. Spangenberg, USN
Adviser: Lieutenant Commander Frederic D. Forney, USN

Maze of Doom
Midshipmen 1/C Justin C. Legg, Mark E. O'Connell and Ryan M. Stofferahn, USN
Adviser: Commander Frederick A. Hoover, USN

Autonomous Underwater Vehicle
Midshipmen 1/C Robert A. Leonard, David M. Pray and Michael J. Uyboco, USN
Adviser: Commander Bradley D. Taylor, USN

Hovercraft
Midshipmen 1/C Daniel A. Levy, Shaun P. Lynch and James R. Prouty, USN
Adviser: Commander John F. McKernan, USN

Robo-Shaq
Midshipman 1/C Marques E. Mackey, USN
Adviser: Lieutenant Commander Franklin D. Hixenbaugh, USN

Diver Communication Systems
Midshipmen 1/C Jason W. McClain and Matthew S. Valle, USN
Adviser: Commander Rodney M. Adams, USNR

Underwater Autonomous Vehicle
Midshipmen 1/C John T. Moore, Patrick J. Sise and Andrew H Tiefenthaler, USN
Adviser: Lieutenant Commander Brent A. Ditzler, USN

The Predator 2000
Midshipmen 1/C Michael G. Mortenson and Warren D. Thompson, USN
Adviser: Commander Jay A. Gutzler, USN

Computerized YP Control
Midshipman 1/C Nathan K. Mote, USN
Adviser: Lieutenant Commander Kenneth L. McElroy, USN

Satellite Ground Station
Midshipman 1/C Sean F. Olone, USN
Adviser: Lieutenant Colonel William W. Arrasmith, USAF

Corporate Takeover
Midshipmen 1/C Christopher R. Rose and Jared W. Wyrick, USN
Adviser: Commander Rodney M. Adams, USNR

The Bear
Midshipmen 1/C Chad L. Ulrich and Scott M. Weinpel, USN
Adviser: Major Thomas L. Langlois, USMC

Systems Ball
Midshipman 1/C Stephen L. Williams, USN
Adviser: Lieutenant Commander Brent A.Ditzler, USN

Publications

AVRAMOV-ZAMUROVIC, Svetlana, Associate Professor, Koffman, Andrew D., Bryan C. Waltrip, Nile M. Oldham, "Uncertainty Analysis for Four Terminal-Pair Capacitance and Dissipation Factor Characterization at 1 MHz and 10 MHz," *IEEE Transactions on Instrumentation and Measurements*, Volume 49, No. 2, (April 2000).

The Electricity Division at the National Institute of Standards and Technology (NIST, formerly NBS) has implemented a system to characterize capacitance and dissipation factor for four terminal-pair (4TP) air dielectric capacitors at frequencies from 1 kHz to 10 MHz . The method is based on work by Cutkosky and Jones of NBS and recent developments by Yokoi, Suzuki, and Aoki as well as Yonekura and Wakasugi of Hewlett-Packard Japan. This paper describes an extensive uncertainty analysis of the measurement system. The analysis has been divided into three areas: 1 kHz capacitance measurements; network analyzer impedance measurements (covering frequencies from 40 MHz to 200 MHz); and a mathematical extrapolation algorithm that regresses the high-frequency characterization down to frequencies of 10 MHz and below. This algorithm is referred to as the capacitor frequency characteristic prediction (CFCP) method. The capacitance and dissipation factor characteristics at 1 MHz and 10 MHz are produced by applying the CFCP algorithm to the 1 kHz capacitance as well as the high-frequency (40 MHz to 200 MHz) impedance measurements.

Capacitors characterized using this technique will be used as impedance reference standards for a general-purpose digital impedance bridge recently developed at NIST to calibrate inductors and ac resistors. The technique is also to be employed in a future NIST Special Test for 4TP capacitance and dissipation factor.

AVRAMOV-ZAMUROVIC, Svetlana, Associate Professor, Andrew D. Koffman, Nile M. Oldham and Brian C. Waltrip, "The Sensitivity of a Method to Predict a Capacitor's Frequency Characteristic," *IEEE Transactions on Instrumentation and Measurements*, Volume 49, No. 2, (April 2000).

Several groups have worked on the characterization of four terminal-pair capacitance standards at high frequencies. The work originally started with Cutkosky and Jones of NIST and was followed by Suzuki, Aoki, Yokoi, Yonekura and Wakasugi of HP Japan. The paper will describe a method to predict a capacitor s frequency characteristic based on the work of Aoki et al. Four terminal-pair air capacitors are considered and regressions of high-frequency network analyzer measurements are used to make predictions. The method is sensitive to regression parameter selection and this paper will give a detailed analysis of the methods that were used to calculate reasonable values for these parameters.

AVRAMOV-ZAMUROVIC, Svetlana, Associate Professor, WICK, Carl, Associate Professor, DEMOYER, Robert, Professor, "Metrology Experiment for Engineering Students: Platinum Resistance Temperature Detector," *Proceedings of the 2000 ASEE Annual Conference*, (June 2000).

This paper describes the use of a platinum resistance temperature detector to develop a calibration experiment and to introduce metrology principles. The Callender-Van Dusen equation is used to analyze the temperature-resistance characteristic of a detector. Linearity of this characteristic is explored using a MATLAB simulation. Resistance is measured at four different temperatures to estimate all of the parameters in Callender-Van Dusen equation. Since the uncertainty of temperature and resistance measurements during calibration determines the accuracy of the temperature measurements using platinum detector, it is necessary to assess the calibration errors. A simulation package is developed that applies different levels of errors into measurements used for parameter estimation. The goal is to study the influence of calibration uncertainty on the temperature detector's readings. The next challenge is a practical realization of the calibration process. A simple experiment is proposed and the least square fit is used to estimate the parameters.

BISHOP, B. E., Assistant Professor, "Instructional Simulation of Mobile Robot Systems," *Proceedings of the IASTED Conference on Modeling and Simulation 2000*, pp. 248-252, May 2000.

In this paper we discuss the use of simulations in robotics instruction, focusing on the appropriate application and integration of simulations in an experimentation-based mobile robotics curriculum. Through examples we examine both the need for and, dangers of, using robot simulations to demonstrate basic principles in mobile robot navigation. Using easily reconfigured graphical simulations, students can be introduced to important concepts in mobile robotics without the necessity for development of many time-consuming experiments, which frequently require a great deal of hardware, space and computing power. The simulations are intended as precursors to real experimentation, allowing for a winnowing of necessary hardware and laboratory space.

BISHOP, Bradley. E., Assistant Professor, "Design of a Cooperative Autonomous Mobile Robot System at the Undergraduate Level," *Proceedings of the 2000 ASEE Annual Conference*, pp. 1-8, June 2000.

This paper describes an undergraduate-level design project in a course on autonomous mobile robot systems. The project is intended to allow a great deal of latitude in implementation and to promote teamwork and integrated design methodologies in a framework that is both instructional and interesting. The technical challenges of the project include limited bandwidth communications, cooperative multi-agent algorithms, data storage and transmission and physical system design/control. Additionally, the project is structured in such a way as to provide the students experience in organizing large teams of cooperative designers and working with small task-dedicated design teams. This design project was a sub-component of a course in Autonomous Robot Design in the Systems Engineering Department at the United States Naval Academy.

BISHOP, Bradley E., Assistant Professor, "On the Use of Controller Switching for Calibration and Control of Monocular Visual Servo Systems," *Proceedings of the 2000 Conference on Information Sciences and Systems*, TP8-21 - TP8-26, April 2000.

In this paper, we present a logic-based switching control architecture for redundant planar monocular visual servo systems with unknown and/or time varying camera/robot calibration. We combine a number of controllers possessing varying calibration requirements with adaptive on-line calibration in order to improve the performance of the switched control system over that of any of the component controllers. Implicit in the controller switching resolution is identification of achievable objectives over each portion of the calibration space, based on the controller suite. The results derived herein may be extended to many visual servo applications.

BISHOP, Bradley E., Assistant Professor, and Spong, Mark W., "Vision-Based Control of an Air Hockey Playing Robot," *IEEE Control Systems Magazine*, pp. 23-32, June 1999.

Robotic manipulation of rapidly moving objects through the application of visual feedback requires careful analysis of the interaction of sensing and control. Selection of achievable manipulation tasks can be carried out through analysis

of the visual data stream when combined with task-specific controllers. Flexibility can be increased in such a system through the use of hybrid control, in which multiple controllers are designed for independent objectives. This article describes vision-based robotic ballistic manipulation using integrated sensing and hybrid control. Experimental results are given for the air hockey example.

BISHOP, Bradley E., Assistant Professor, and Spong, Mark W., "Vision-Based Objective Selection for Robust Ballistic Manipulation," Robust Vision for Vision-Based Control of Motion, (Markus Vincze and Gregory D. Hager, eds.), *IEEE Press*, pp. 203 - 219, 1999.

The use of visual measurement for high-speed and high-precision robotic tasks requires careful analysis of the fundamental properties of the sensing paradigms chosen. In this work we analyze the information generated by a state estimator for a target moving object that is to be intercepted by a robotic manipulator. Selection of potential interaction objectives is carried out through analysis of the data stream from the visual system. The underlying sensing problem is designed for a fundamentally unstructured environment under fixed-camera visual measurement. The test domain is chosen to be ballistic manipulation of a sliding object on a low-friction planar surface: the air hockey problem.

BISHOP, Bradley E., Assistant Professor, PIPER, George E., Associate Professor, and O'BRIEN, Richard T., Assistant Professor, "The Light-Tracker: An Off-The-Shelf Control Design Project," *Proceedings of the 1999 ASEE Annual Conference*, Session 2532, pp. 1-7, June 1999.

This paper describes the development of an off-the-shelf design project in applied control. The project is aimed toward developing insight into the design process through an open-ended, hands-on experimental procedure. Reinforcement of classroom topics and introduction to the difficulties of real design are emphasized. Particular focus is placed on the flow of system development, from problem statement, component selection and system identification through implementation and tuning of a PD controller. This design project has been integrated into the junior level curriculum in the Systems Engineering department at the United States Naval Academy.

DeMOYER, Robert, Professor, and MITCHELL, E. Eugene, Professor, "Use of the MATLAB Graphical User Interface Development Environment for Some Control System Applications," *Proceedings of Frontiers in Education*, CD-ROM, (November 1999).

New with MATLAB 5 is the Graphical User Interface Development Environment, or GUIDE. This tool enables the engineering educator to produce pedagogical software which combines the computing and graphics capability of MATLAB with convenient Graphical User Interfaces.

A brief overview of handle graphics is provided, followed by the introduction of GUIDE. GUIDE is used alone to produce an elementary example, and is used in combination with other files in order to produce a more interesting example.

DWAN, Terrence E., Professor, MITCHELL, E.E., Professor, and PIPER, G.E., Associate Professor, "The Environmental Box: A Design Project," *Proceedings of the Modeling and Simulation Conference*, IASTED, pp 262-264, June 2000.

Environmental topics such as pollution prevention, pollution remediation, natural resource utilization, as well as global and local weather studies, provide excellent catalysts to teach a wide breadth of engineering principles. For the past three years, the Systems Engineering and the Ocean Engineering Departments at the U.S. Naval Academy have collaborated to offer an innovative sequence in Environmental Engineering. In this paper we discuss our approach to an interesting design medium called the Environmental Box. The sensing, data gathering and data analysis of environmental parameters in a design context are given in the paper. Also, several student results are shown.

KIRIAKIDIS, Kiriakos, Assistant Professor, "Nonlinear Control System Design via Fuzzy Modeling and LMIs," *International Journal of Control*, 72, pp. 676-685, July/August 1999.

Fuzzy modeling and model based control offer alternative solutions to analysis and synthesis problems associated with many systems that exhibit complex nonlinear behavior. A prominent advantage of these approaches has been their ability to work without resorting to first principles or engaging elaborate controllers whose performance in a changing environment will deteriorate inevitably. The present paper facilitates further advances in the field through the development of a framework that embraces the vast majority of the existing fuzzy model based control techniques and provides novel means to design nonlinear control systems for a variety of applications. The proposed design methodology exploits the distinctive property of the fuzzy model as the convex hull of linear system matrices. Using this quasi—linear model structure, the robust stabilization of nonlinear systems, against modeling error and parametric uncertainty, based on static state or dynamic output feedback is formulated and solved as a Linear Matrix Inequality (LMI) problem.

KIRIAKIDIS, Kiriakos, Assistant Professor, "Takagi-Sugeno Fuzzy Modeling and Control: Unmodeled Dynamics and Robustness," *Proceedings of the 38th IEEE Conference on Decision and Control*, pp. 4361-4363, December 1999.

The Takagi-Sugeno (TS) fuzzy modeling approach has been very successful in approximating complex dynamics and hence has offered a basis for analysis and design in many control applications where conventional modeling is impossible. At present, a drawback of the TS fuzzy model is the high dimension of its information space, which, in turn, necessitates a large number of local linear models to cover a certain region of such space. This article shows that the dimension of the information space is reducible only at the expense of modeling error. The article also suggests a robust controller that tolerates a certain amount of such modeling error.

Gordon, D. and KIRIAKIDIS, Kiriakos, Assistant Professor, "Adaptive Supervisory Control of Interconnected Discrete Event Systems," *IEEE Conference on Control Applications*, pp. 935-940, September 2000.

Interconnections of discrete event systems are able to model large-scale structures. These structures, however, are often subject to change. At present, the literature on supervisory control offers only a few remedies for the synthesis of adaptive or robust discrete event systems. This paper proposes an approach to adaptive supervision based on machine learning.

KNOWLES, Kenneth A., Professor, "A Modern Teaching Environment for Modeling and Simulation," *Proceedings of the 2000 IASTED Pittsburgh Modeling and Simulation Conference*, May 2000.

Engineering education in the 21st century can best be characterized by the requirement of web centric connections at each student location, multimedia presentation capability, and compatibility with a multitude of learning and teaching styles. The use of electronic textbooks, online experts, and cooperative simulation and design environments must be anticipated. These concepts have been fully integrated into the design of the upcoming year-long renovation of Maury Hall at the United States Naval Academy, which houses the classrooms and laboratories of the Weapons and Systems Engineering Department. In order to verify many of the design concepts, and to gain experience in their effective use, a test facility, presumptuously referred to as the "Classroom of the Future", currently is being brought online. Although not fully complete, the facility is now supporting five sections of one of the laboratory-based elective courses in the Systems Engineering major. One of the main features of this facility is complete laboratory (and Internet) network connectivity at each of the re-locatable student desks using supplied laptop computers. Student use and instructor-student interaction with some of the popular simulation programs to investigate and design computer and control systems is greatly facilitated by this feature. The following paper describes the features of this experimental combined classroom/laboratory facility and provides some of the preliminary lessons learned through its early use.

O'BRIEN Jr., Richard T., Assistant Professor, MITCHELL, E. Eugene, Professor, and MCCLOY, Darin, MAJ, USMC,"Economic Analysis of Windmill and Solar Energy Sources for Undergraduate Engineering Students", Proceedings of IASTED International Conference on Modeling and Simulation, May 2000, 253-256.

The diminishing availability of fossil fuels necessitates the investigation of alternative energy sources. Solar and wind power are two important alternative energy sources because these sources are renewable. In this paper, a possible scenario is examined where a solar panel and wind mill are used to reduce a homeowners dependence on utility power. The system uses power generated by the solar panel and windmill to power household appliances. The system has a connection to utility power to periodically charge the battery. The control system monitors the battery charge and decides to either charge the battery or dump power if the battery is fully charged. The battery is charged using excess power from the solar panel and windmill, when available, and utility power, otherwise. If the system needs to dump power, it is sold back to the utility. The design parameter in this project is the capacity of the battery and this capacity will be chosen to minimize the operational cost of the system. The operational cost is determined from three factors: the cost of battery power, the cost of utility power, and the profit earned from selling power back to the utility. In this project, the students construct a simulation of the system and use the simulation to select the desired battery capacity.

O'BRIEN Jr., Richard T., Assistant Professor, and Iglesias, Pablo A., "Robust Controller Design for Linear, Time-Varying Systems," *European Journal of Control*, 5(2) 222-241, August 1999.

This paper examines the design of controllers for linear, time-varying systems. A design procedure is presented that incorporates performance and robustness objectives into existing H-infinity optimal control methods for time-varying systems. Design guidelines are derived for several basic performance and robustness objectives using a description of the frequency domain behavior of a time-varying system. The frequency response is dependent on time as well as frequency. These guidelines reflect the frequency domain intuition gained from the time-invariant case as well as the time-dependence of the frequency domain behavior of a time-varying system. Performance specifications are incorporated through the selection of time-varying weighting filters. Time-varying realizations for the weighting filters are obtained by interpolating between time-invariant realizations. Results on the localized-in-time behavior of these realizations are derived to permit localized-in-time performance specifications. This procedure is analogous to the loop shaping design procedure of McFarlane and Glover for time-invariant systems.

O'BRIEN Jr., Richard T., Assistant Professor, WATKINS, John A., Assistant Professor, PIPER, George E., Associate Professor, and David C. Baumann, "Robust Global Control Of Fan Noise in an Acoustic Duct Using Magnetic Bearings," *Proceedings of 1999 Conference on Decision and Control*, December 1999, pp. 2605 – 2610.

In this paper, a novel approach is presented to reduce fan related noise in an acoustic duct. By installing magnetic bearings on the noise producing machinery, it is possible to co-locate the anti-noise source with the disturbance noise source. This approach allows for global noise reduction through out the duct system. Using H-infinity control theory, an active noise controller is designed that attains broadband as well as tonal noise reduction at all points along the duct. H-infinity control designs are particularly robust to uncertainties in the plant model. Finally, simulation results demonstrate the global nature of this novel active noise control approach.

O'BRIEN Jr., Richard T., Assistant Professor and WATKINS, John M., Assistant Professor, "The Temperature Box: An Introductory Control Systems Project," *Proceedings of 1999 Conference on Decision and Control*, December 1999, pp. 797 – 801.

There is a heightened awareness in the academic controls community about the need to attract the best and brightest students to the discipline. To achieve this end, change is needed in the standard approaches to educating, recruiting, and training students. In this paper, the "Temperature Box" experiment is presented. This experiment involves the design and implementation of a feedback temperature control system. At the United States Naval Academy, the Temperature Box is used to motivate the material in an introductory system engineering course at the sophomore level. This experiment would also be suitable for use in a freshman engineering course, a control systems laboratory course, or an electronics course as a controls application of analog and digital electronics.

PIEPMEIER, Jenelle A., Assistant Professor, G.V. McMurray, and H. Lipkin, "Experimental Results Using Vision-Based Control for Uncalibrated Robotic Systems," *Proceedings of SPIE: Intelligent Robots and Computer Vision XVII: Algorithms, Techniques, and Active Vision*, vol. 3837, pp. 98-107, September 1999.

This work demonstrates a vision-based control technique that does not require robot or vision system calibration. There are two distinct advantages: first, the approach is generic and can be applied to a variety of systems; second, calibration is unnecessary after a reconfiguration or disturbance to the robotic workcell. It has the potential to provide a low-cost, low-maintenance automation solution for unstructured industries and environments. The robot end-effector tracks a moving target using a novel dynamic quasi-Newton control law formulated in the image plane and on-line Jacobian estimation using either a dynamic Broyden's method or a dynamic recursive least squares algorithm. Experimental results demonstrate convergent and stable control of an uncalibrated manipulator tracking a moving target. The method is shown to be robust to system reconfiguration such as modifications to the position and orientation of the camera.

PIEPMEIER, Jenelle A., Assistant Professor, McMurray, G.V., and Lipkin, H., "A Dynamic Jacobian Estimation Method for Uncalibrated Visual Serving." *IEEE/ASME International Conference on Advanced Intelligent Mechatronics*, pp. 994-999, September 1999.

A dynamic Broyden's method is presented for use in a quasi-Newton control scheme for model-independent vision guided robotic control. Model independent visual servo control is defined as using visual feedback to control a robot without precisely calibrated kinematic and camera models. The control problem is formulated as a nonlinear least squares optimization. For the moving target case, this results in a time-varying objective function which is minimized using a dynamic Newton's method. The dynamic Broyden update is used to estimate the combined robot and image Jacobians. Experimental results for a two-degree-of-freedom system demonstrates the success of the algorithm.

PIEPMEIER, Jenelle A., Assistant Professor, McMurray, G.V., A. Pfiefer, and Lipkin, H., "Uncalibrated Target Tracking with Obstacle Avoidance." *IEEE International Conference on Robotics and Automation*, vol. 2, pp. 1670-1675, April 2000.

Target tracking and obstacle avoidance are demonstrated for uncalibrated visual servoing. An objective function is designed that encourages target following by a robotic end-effector while discouraging movements near an obstacle. The objective function incorporates the error between the target and the end-effector and a potential function related to the obstacle. This objective function is minimized using a dynamic nonlinear least squares optimization method in conjunction with a recursive least squares Jacobian estimation algorithm. The approach is generic and can be applied to a variety of systems. Calibration is unnecessary after a reconfiguration or disturbance to the robotic workcell. This type of control has the potential to provide a low-cost, low-maintenance automation solution for instructured industries and environments. Experimental results demonstrate both target tracking and obstacle avoidance for an uncalibrated robotic system.

PIEPMEIER, Jenelle A., Assistant Professor, McMurray, G.V., Pfiefer, A., and Lipkin, H., "Uncalibrated Target Tracking With Joint Limit Avoidance." *IASTED Simulation and Modeling Conference*, pp. 237-242, May 2000.

Target tracking and joint limit avoidance are demonstrated for uncalibrated visual servoing using a simulation of a five degree-of-freedom robot with stereo vision. An objective function is designed that encourages target following by a robotic end-effector while discouraging large joint angles. The idea is to avoid the joint limits of the system without using a kinematic model or camera model. The objective function incorporates the error between the target and the end-effector and the joint angle values for the rotary joints. Thus the goal is to minimize image error and encourage the smallest possible joint angles This objective function is minimized using a dynamic nonlinear least squares optimization method in conjunction with a recursive least squares Jacobian estimation algorithm. The approach is generic and can be applied to a variety of systems. Calibration is unnecessary after a reconfiguration or disturbance to the robotic workcell. This type of control has the potential to provide a low-cost, low-maintenance automation solution for unstructured industries and environments.

PIPER, George E., Associate Professor, and O'BRIEN, Richard T., Assistant Professor, "On the Effects of Fuel Motion During Spacecraft Docking Maneuvers," *Proceedings of the IASTED/ISMM International Conference on Modeling and Simulation*, pp. 243-245 (May 2000).

This paper investigates the potential problems associated with fuel motion during spacecraft docking maneuvers. A simple translational model is used to demonstrate the interaction between fuel motion and spacecraft's position control systems during docking maneuvers.

PIPER, George, Associate Professor, WATERS, J., Assistant Professor, DWAN, T.E., Professor and KIRIAKIDIS, Kiriakidis, Assistant Professor, "Teaching Multidisciplinary Engineering Principles Through Environmental Topics," *Proceedings of the ASEE Annual Conference and Exposition*, (June 2000).

For the past three years, the Systems Engineering and the Ocean Engineering Departments at the U.S. Naval Academy have collaborated to offer an innovative course sequence in environmental engineering. In this course sequence, a host of engineering principles are explored under the umbrella of environmental topics for non-environmental engineering students. This paper presents the techniques used in this course sequence in which engineering principles are either taught or reinforced, and then applied to a real system or problem through environmental topics.

STILWELL, Daniel J., Assistant Professor, and Rugh, Wilson J., "Interpolation of Observer State Feedback Controllers for Gain Scheduling," *IEEE Transactions on Automatic Control*, Volume 44, Number 6, 1225-1229, June 1999.

A proposed method of interpolating linear time-invariant controllers with observer state feedback structure in order to generate a continuously-varying family of controllers that stabilizes a family of linear plants. Gain scheduling is a motivation for this work, and the interpolation method yields guidelines for the design of gain scheduled controllers. The scheduling method is illustrated with the design of a missile autopilot using loop-shaping H-infinity controllers.

STILWELL, Daniel J., Assistant Professor, and Rugh, Wilson J., "Stability Preserving Interpolation Methods for the Synthesis of Gain Scheduled Controllers," *Automatica*, Volume 36, Number 5, 665-671, May 2000.

Synthesis of gain scheduled controllers for nonlinear plants often requires that a parameter-varying controller be generated from a finite set of linear time-invariant controllers. We propose interpolation methods for this task with the property that stability of the linearized closed-loop system is preserved for all values of the scheduling parameter. In addition, slow-variation arguments are presented that establish local stability of the nonlinear closed-loop system with gain scheduled controller.

STILWELL, Daniel J., Assistant Professor, "On the Use of Slow-Variation Arguments in Gain Scheduled Control," *Proceedings of the Conference on Information Systems and Sciences*, pp. TP8-TP10, March 2000.

Slow-variation arguments are standard tools for stability analysis of gain scheduled systems. A bound on the time-derivative of the scheduling variable is computed that assures stability of the nonlinear closed-loop system. We show that it is also possible to impose a bound on the average time-derivative of the scheduling variable. Merits of both approaches are investigated through the stability analysis of a gain scheduled controller design example.

STILWELL, Daniel J., Assistant Professor, and BISHOP, Bradley E., Assistant Professor, "A Framework for Decentralized Control of Autonomous Vehicles," *Proceedings of IEEE International Conference on Robotics and Automation*, pp. 2358-2363, April 2000.

Decentralized control of multiple mobile robots for cooperative tasks often requires not only environmental sensing but communication among the robot subsystems. In this work, we develop observer—based methods for characterizing the implicit and explicit communications required for a swarm of robots to successfully achieve classes of control objectives.

STILWELL, Daniel. J., Assistant Professor, "J-Q Interpolation for Gain Scheduled Controllers," *Proceedings of the IEEE Conference on Decision and Control*, pp. 3483-3488, December 1999.

We propose a method for interpolating state-space descriptions of linear time-invariant controllers in order to generate a continuously-varying family of controllers that stabilizes a family of linear plants. The interpolation method is based on state-space Youla parameterization of the controllers and is well-suited for the synthesis of gain scheduled controllers. Our approach is illustrated with the design of a gain scheduled missile autopilot.

WATKINS, John M., Assistant Professor, PIPER, George E., Associate Professor, O'BRIEN, Richard T., Assistant Professor, and Baumann, David C., "The Use of Magnetic Bearings for Global Control of Fan Noise," *Proceedings of the American Control Conference*, pp. 581-585, June 1999.

In this paper, a novel approach is presented to reduce fan related noise in an acoustic duct. By installing magnetic bearings on the noise producing machinery, it is possible to collocate the anti-noise source with the disturbance noise source. This approach allows for global noise reduction through out the duct system.

WICK, Carl E., Associate Professor, and PIPER, George E., Associate Professor, "Teaching DSP Servo-Motor Control with Extended SHARC Evaluation Boards; The Pilot-Fish Project," *Proceedings of the 1999 Frontiers in Education(FIE) Conference*, (November 1999).

In this paper we discuss a locally-generated daughter-board extension to the popular SHARC DSP evaluation module (EVM). The board improves the performance of this inexpensive hardware in many applications that involve feedback control. We discuss the use of this hardware in a simple servo-motor control experiment that demonstrates many of the fundamentals of digital signal processor control of physical plants.

WICK, Carl E., Associate Professor and KNOWLES, Kenneth A., Professor, "USS Tanglewire: An Experiment in Networking for an Embedded Computer Applications Class," *Proceedings of the 2000 ASEE Annual Conference*, (June 2000).

Small embedded microprocessors are used routinely as controllers in many types of consumer, industrial, and military electronic devices. In many cases, more than one of thee small computers are used in a single product to effect distributed control, or to localize specific system functions. This tends to modularize the system and helps to make it more reliable, survivable, configurable, and upgradable. Networks provide the "glue" that connects each of the localized modules together into a functioning whole. We believe that students who take courses in microprocessor embedded control should have some exposure to network-connected control systems, and if possible, they also should have experience in the implementation of these systems. This paper describes a project that we undertook at the U. S. Naval Academy in our computer engineering track where our students used the I^2C network and PIC 16C84 microprocessors to construct a model distributed shipboard damage control system.

Lively, Kenneth, MCCOY, Timothy J., Lieutenant Commander, USN, Thompson, Tracey, and ZIVI, Edwin L., Assistant Professor, "USN Advanced Control Concepts for an Integrated Power System (IPS) Warship," *Proceedings of the INEC 2000 Conference*, Hamburg, Germany, (March 2000).

The Integrated Power System is in the midst of its full scale advanced development testing phase. As the various functional, interface and interoperability issues become resolved, the focus is shifting to the overall system control logic optimization, the interfaces to various supporting systems, and the interface to the ship's mission controllers.

The paper describes the current architecture of the IPS and the current controls concepts. Outstanding design issues such as power flow management, maximal autonomy of lower level controllers and network physical and logical interfaces are then explored. Additionally, the controls requirements represented by the interdependencies of the IPS with the supporting auxiliary systems and the requirements placed on the IPS by the ongoing reduced manning initiatives are analyzed. Solutions to these areas consistent with a minimally manned system that is affordable, dependable and survivable are then discussed. A viable architecture and function for a future IPS combatant is then presented, based on the technology trends and research efforts reviewed. Areas for further investigation are suggested.

ZIVI, Edwin L., Assistant Professor and CERRITO, Jonathan J., Midshipman 1/C, "Neural Network Fault Tolerant Control of an Integrated Power System," *Proceedings of IASTED Modeling and Simulation 2000 Conference*, International Association of Science and Technology for Development, (May 2000).

A feed forward back-propagation neural network is investigated for fault tolerant stabilization and control of an Integrated Power System (IPS). Neural networks can be robust in the sense that they are not disabled by incomplete or inconsistent information. The ability of a neural network to adapt to unforeseen eventualities such as flooding, fire, and combat casualties was investigated for a complex, interactive power system. The IPS under consideration will provide integrated propulsion and ship's service power generation and distribution for the next generation of U.S. Navy surface ships also known as the DD-21. These solid state power systems involve nonlinear dynamics which exhibit "negative impedance" can leading to instability and voltage collapse. This research represents an initial step toward unifying nonlinear, negative impedance stabilization with robust neural network fault detection and isolation. The Naval Sea Systems Integrated Power System and the Office of Naval Research Electrically Reconfigurable Ship programs motivated this research.

WELCH, Thad B., Commander, USN, ZIVI, Edwin L., Assistant Professor, FIELD, Christopher, Assistant Professor, and Rice, Josette, Commander, USN, "Real-time Data Acquisition in a Signals and Systems Course," *Proceedings of ASEE 2000 Annual Conference*, American Society for Engineering Education, (June 2000).

A sophomore or junior level course entitled *Signals and Systems* or *Linear Systems Theory* is contained within almost every electrical engineering program in the country. The United States Naval Academy offers a junior level *Signal and Systems* course that includes a significant amount of hands-on lab time. This course is taught in a 2-2-3 format. The availability of both PCs and DAQ software that allow for seamless introduction of real-world data into the MATLAB workspace has facilitated this process. This paper discusses some of the lab exercises that are used in this course. These lab experiments have allowed our students to see immediate applicability for the theory and skills that they are learning in class.

Presentations

BISHOP, Bradley. E., Assistant Professor, "Instructional Simulation of Mobile Robot Systems," Conference on Modeling and Simulation, Pittsburgh, PA, May 2000.

BISHOP, Bradley. E., Assistant Professor, "The Light Tracker: An Off-the-Shelf Control Design Project," ASEE Annual Conference 1999, Charlotte, NC, June 1999.

BISHOP, Bradley. E., Assistant Professor, "On the Use of Controller Switching for Calibration and Control of Monocular Visual Servo Systems," 2000 Conference on Information, Signals and Systems, Princeton, NJ., April 2000.

DeMOYER, Robert, Professor, "Use of the MATLAB Graphical User Interface Development Environment for Some Control System Applications," Frontiers in Education FIE '99, San Juan, Puerto Rico, November 1999.

DWAN, Terrence E., Professor, "The Environmental Box", IASTED International Conference on Modeling and Simulation, Pittsburgh, PA, May 2000.

KIRIAKIDIS, Kiriakos, Assistant Professor, "Takagi-Sugeno Fuzzy Modeling and Control: Unmodeled Dynamics and Robustness," IEEE Conference on Decision and Control, Phoenix, AZ, December 1999.

KIRIAKIDIS, Kiriakos, Assistant Professor, "Adaptive Supervisory Control of Multi-agent Systems," Goddard Workshop on Formal Approaches to Agent-Based Systems, Greenbelt, MD, April 2000.

KNOWLES, Kenneth A., Professor, "A Modern Teaching Environment for Modeling and Simulation," 2000 IASTED Pittsburgh Modeling and Simulation Conference, Pittsburgh, PA, May 2000.

KNOWLES, Kenneth A., Professor, "NASA and Ten Years of the Hubble Space Telescope," Moorefield High School, Moorefield, West VA, May 2000.

O'BRIEN, Richard, Assistant Professor, E. Eugene MITCHELL, Professor and Major Darin J. MCCLOY, USMC, "Economic Analysis of Alternate Energy Sources for Undergraduate Engineering Students," IASTED Conference on Modeling and Simulation, Pittsburgh, PA, May 2000.

O'BRIEN, Richard T., Assistant Professor, "The Light Tracker: An Off-the Shelf Control Design Project", Proceedings of the 1999 ASEE Annual Conference, Charlotte, NC, June 1999.

O'BRIEN, Richard T., Assistant Professor, "Robust Global Control Of Fan Noise In An Acoustic Duct Using Magnetic Bearings," Proceedings of 1999 Conference on Decision and Control, Phoenix, AR, December 1999.

O'BRIEN, Richard T., Assistant Professor, "The Temperature Box: An Introductory Control Systems Project," Proceedings of 1999 Conference on Decision and Control, Phoenix, AR, December 1999.

O'BRIEN, Richard T., Assistant Professor, "Economic Analysis of Windmill and Solar Energy Sources for Undergraduate Engineering Students," Proceedings of IASTED International Conference on Modeling and Simulation, Pittsburgh, PA, May 2000.

PIEPMEIER, Jenelle A., Assistant Professor, "Experimental Results Using Vision-Based Control for Uncalibrated Robotic Systems," Intelligent Robots and Computer Vision XVII: Algorithms, Techniques, and Active Vision. Boston, MA, September 1999.

PIEPMEIER, Jenelle A., Assistant Professor, "Model Independent Visual Serving." Presentation for Intelligent Systems Division, National Institute of Standards and Technology, Gaithersburg, MD, November 2000.

PIEPMEIER, Jenelle A., Assistant Professor, "Uncalibrated Target Tracking with Obstacle Avoidance." IEEE International Conference on Robotics and Automation, San Francisco, CA April 2000.

PIEPMEIER, Jenelle A., Assistant Professor, "Uncalibrated Target Tracking With Joint Limit Avoidance." IASTED Simulation and Modeling, Pittsburgh, PA, May 2000.

PIPER, George E., Associate Professor, and O'BRIEN, Richard T., Assistant Professor, "On The Effects Of Fuel Motion During Spacecraft Docking Maneuvers", presented at the IASTED/ISMM International Conference on Modeling and Simulation, Pittsburgh, PA, May 2000.

STILWELL, Daniel J., Assistant Professor, "Interpolation Methods for the Synthesis of Gain Scheduled Controllers," Electrical and Computer Engineering Department, University of Massachusetts, Amherst, MA, May 2000.

STILWELL, Daniel J., Assistant Professor, "A Framework for Decentralized Control of Autonomous Vehicles," IEEE International Conference on Robotics and Automation, San Francisco, CA, April 2000.

STILWELL, Daniel J., Assistant Professor, "On the Use of Slow-variation Arguments in Gain Scheduled Control," Conference on Information Systems and Sciences, Princeton, NJ, March 2000.

STILWELL, Daniel J., Assistant Professor, "J-Q Interpolation for Gain Scheduled Controllers," IEEE Conference on Decision and Control, Phoenix, AZ, December 1999.

WATKINS, John M., Assistant Professor, and PIPER, George E., Associate Professor, "The Use of Magnetic Bearing for Global Control of Fan Noise", 1999 American Control Conference, San Diego, CA, June 1999.

WATKINS, John M., Assistant Professor and E. E. MITCHELL, Professor, "A MATLAB Graphical User Interface for Linear Optimal Control Design," ASEE National Conference, St. Louis, MO, June 2000.

WICK, Carl E., Associate Professor, and PIPER, George E., Associate Professor, "Teaching DSP Servo-Motor Control with Extended SHARC Evaluation Boards; The Pilot-Fish Project," 1999 FIE Conference, San Juan, PR, November 1999.

ZIVI, Edwin L., Assistant Professor, "Neural Network Fault Tolerant Control of an Integrated Power System," IASTED Modeling and Simulation 2000 Conference, International Association of Science and Technology for Development, Pittsburgh, PA, May 2000.

ZIVI, Edwin L., Assistant Professor, "Interactive Root Locus Design Using MATLAB Graphical User Interface," ASEE 2000 Annual Conference, American Society for Engineering Education, St. Louis, MO June 2000.

ZIVI, Edwin L., Assistant Professor, "Neural Network Fault Tolerant Estimation of an Integrated Power System," Applied Simulation and Modeling Conference, Banff, Canada, July 2000.