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 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 was one Trident Scholar in the Systems Engineering Department. The scholar engaged in an extensive research project in lieu of several courses. Strong emphasis continues on the faculty-midshipman relationship during the individual research oriented capstone design course. Each midshipman is assigned both an administrative and a technical 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. Funding sponsors this year included the Naval Academy Research Council (NARC), the Office of Naval Research (ONR), the Naval Research Lab (NRL), the Naval Surface Warfare Center (NSWC), and the National Institute of Standards and Technology (NIST).

Sponsored Research

Atlantic Center for the Innovative Design of Small Ships

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

Novel hull designs and locomotive capabilities for littoral craft will require substantial automation in order to achieve minimum manning, maximal power efficiency and optimal performance. Additionally, automation can be used to enhance safety and minimize environmental impact. The primary focus of this project is to provide pilot assistance for small manned craft in littoral scenarios. This work is 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 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 bases for these techniques are environmental sensing and appropriate modeling. A number of sensing modalities are being investigated, and efficient techniques are being 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 is being 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.

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

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

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

Electric Helicopter Surveillance Vehicle Demonstration

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

The objective of Electric Helicopter Surveillance Vehicle is to demonstrate close line-of-sight control for direct support of unmanned vehicles for Special Forces and front line Marine Corps and Army combat troops. Operations in Afghanistan demonstrated the critical role that unmanned vehicles play in current and future operations. However, deficiencies were identified in that most current Unmanned Air Vehicle (UAV) systems are controlled by operators at remote locations. Front line combat troops do not have direct access to the imagery from onboard sensors. They also must attempt to talk remote operators onto targets to obtain reconnaissance or direct fire support. This project involves 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.

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

Researchers: Dr. Michael Bruno (Stevens Institute), Assistant Professor Jenelle A. Piepmeier
and Associate Professor Jennifer K. Waters (Naval Architecture and Ocean Engineering Department)
Sponsor: Office of Naval Research (ONR)

The Atlantic Center for Innovative Design is a consortium of individuals from Stevens Institute of Technology, University College of London, Webb Institute, the U.S. Naval Academy, and a number of industry partners. The Center proposes to address meet the Navy's new and emerging needs in the littoral zone by focusing on two key areas. Current research is investigating vision-based sensing methods to provide sea state estimation for improved sea-keeping. During the 2004 academic year, projects with Midshipman 1/C J. Grob's have successfully used stereo vision to capture three-dimensional surface measurements of regular waves. It is believed that this is the first time three-dimensional surface data of a wave surface has been collected using stereo imaging. Wave heights and frequencies have been measured and compared with traditional wave gages.

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

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

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

Submarine Towed Acoustic Reference System (STARS)

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

Software was developed for the analysis of data from the Submarine Towed Acoustic Reference System (STARS). This is a towed buoy equipped with GPS whose position relative to the submarine is determined acoustically. The task involved creating a phase-locked loop implementation in software to separate 12 acoustic tones on a single channel into 3 tones for each of four array elements to determine the position of the buoy relative to the SSBN.

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 supported the testing and standardization of computer forensics software that is accomplished by the Computer Forensics Division of NIST. Computer forensic efforts often entail the examination and collection of data from personal computer hard disk drives. If data taken from disk drives is to be used as evidence in court proceedings, there must be established confidence that the software does not change data in any manner during collection. The disk drive monitor and simulator developed in this project is a device that electrically monitors all disk drive activity external to the hardware that the disk is connected to, and external to any software that is exercising the disk drive. The device plugs into the system between a PC and a disk drive and is able to record and report all disk drive accesses (commands and data) by the host PC. The device is also able to simulate various hard drive errors during disk accesses and to record the resulting program reactions that may occur in response to errors.

National Naval Requirement (NNR) Electric Ship Integration (ESI)

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

The future U.S. Navy requires a *transformative* ship design for an Electric Warship. As noted in the 2001 Quadrennial Defense Review, *"Transformation is not a goal for tomorrow, but an endeavor that must be embraced in earnest today"*. The Naval Research Advisory Committee (NRAC) Roadmap to an Electric Naval Force and other studies have identified electric weapons coupled with superior mobility, stealth, endurance, reconfigurability, and survivability as motivations for an electric naval force. Concurrently, the ability to system engineer fundamentally new ship designs has been identified as the primary remaining obstacle. This collaborative research and curricula innovation serves as a catalyst for the transformation to a more agile, effective, robust, and affordable naval presence by emphasizing:

- ***Multidisciplinary Ship Design*** - led by the Massachusetts Institute of Technology (MIT) Ocean Engineering Department and the 13A Naval Construction program,

- ***Integrated Power System Analysis*** - led by Purdue University and the University of Missouri at Rolla leveraging existing Naval Combat Survivability test beds and expertise, and
- ***Automation System Engineering*** - led by the United States Naval Academy.

Collectively, these organizations provide established and sustained core USN educational and research resources. The technical thrusts at the U.S. Naval Academy include: Automation, Systems Engineering, Ship Service Power Distribution, and Distribution Control.

Distributed Automation Design for Survivability

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

This research introduces essential systems design methods and tools in support of the transformation of naval force projection outlined in Seapower 21 and various Naval Research Advisory Committee (NRAC) studies. Key system design innovations involve the introduction of survivability as an independent variable and incorporation of the dynamic interdependence of advanced engineering and damage control architectures, technologies, and automation strategies. Stochastic and evolutionary computing is used to evaluate system integrity and fault tolerance with respect to complex combat induced disruptions. New "system of systems" design methods and metrics are under development in collaboration with the Georgia Institute of Technology Aerospace Systems Design Laboratory, Purdue University, and the Massachusetts Institute of Technology Ocean Engineering Department. This research collaboration builds on established expertise and partnerships to serve as a catalyst for revolutionary system design methods and tools for a more agile, effective, robust, and affordable naval presence. Thrust areas include: distributed automation system design; automation concepts and technology; and evolutionary computing for survivability assessment.

Independent Research

Test Generation for Embedded Control Systems

Researcher: Assistant Professor Joel M. Esposito

This goal of this project 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 being explored.

Output Feedback Tracking Controller for a Class of Nonlinear Systems

Researcher: Assistant Professor Matthew G. Feemster

A linear, output feedback control strategy is being investigated for a nonlinear class of single-input, single-output (SISO) systems satisfying a linear growth function. Specifically, the intended output feedback controller will couple a linear observer structure with a corresponding linear control design in order to drive the output tracking error signal to within an arbitrarily small region about zero. Simulation of a representative system is being investigated to verify the performance and mechanics of implementation.

Trident Scholar Project

Synthesis of a Controller for Swarms of Robots Performing Underwater Mine Countermeasures (Trident Report # 328)

Researcher: Midshipman 1/C Yong C. Tan, USN
Adviser: Associate Professor Bradley E. Bishop
Sponsor: Office of Naval Research (ONR)

This project involved the study of control techniques for a group of swarming robots performing underwater mine countermeasures (UMCM). A robot swarm is a group of autonomous robots working collectively to perform a task. An important application of this research is the utilization of numerous cooperating Autonomous Underwater Vehicles (AUVs) to conduct UMCM. Implementation of such a system will dramatically reduce the danger posed to human operators and high value units, usually ships, while increasing efficiency.

Two approaches for swarm control, the systems theoretic and behavior-based methods, were implemented in simulation to determine their suitability for robotic UMCM. These two methods were found to be compatible for combination and hybridization. Hybridization served to accentuate the strengths of both techniques and to reduce their weaknesses, making the hybrid a qualitatively more robust controller.

The main objective of this research was to combine behavior-based control methods with system theoretic swarm control techniques to achieve a hybrid that had the best characteristics of both. The simulations generated demonstrated the characteristics of the parent controller as well as those of the hybrid. Additional simulations highlighted the improved performance of the hybrid controller versus the other controllers under more realistic environmental situations with drift (current), obstacles and mines.

Midshipman Research Course Projects

Direction Finding Using a Reconfigurable Array

Researcher: Midshipman 2/C Danica L. Adams, USN
Advisers: Associate Professor Richard T. O'Brien, Jr., and Associate Professor Kiriakos Kiriakidis

The proposed project was an initial investigation into a multi-array that comprises a network of mobile autonomous arrays of sonar sensors. Each array operates autonomously to estimate the direction of arrival (DOA) and then attempts to maximize the received signal strength. The aforementioned use of arrays assists in the processing of the acoustical information in the multi-array. The goal of this project was to investigate the feasibility of the design of the constituent arrays, in preparation for a Trident Scholar project during the 2005 academic year.

Assessment of DC Stability Toolbox Application to Shipboard Nonlinear Integrated Power System

Researcher: Midshipman 1/C Ryan J. Corcoran, USN
Adviser: Assistant Professor Edwin L. Zivi
Sponsors: Bowman Scholar Program (BSP) and Office of Naval Research (ONR)

A critical element of the Navy's future electric warships will be a robust Integrated Power System for propulsion, ship's service, and weapons. To achieve this robustness, more survivable control strategies need to be developed to efficiently and effectively distribute power to needed loads despite casualties and large-scale disturbances to the power system. Since accurate nonlinear simulation models are essential for effective control strategies, two nonlinear test bed simulation models were investigated and compared to hardware test bed results. A secondary research objective involved the assessment of the MATLAB-based DC Stability Toolbox for large signal disruptions. This investigation concentrated on an in-depth comparison between two of the time-domain test bed simulations. This in-depth knowledge of the time-domain simulations will allow more flexibility in selection of control strategies for representative combat casualty scenarios.

Small Watercraft Automation: Sensing

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

This project focused on the sensing aspects of the design of a watercraft automation test platform. The primary objectives of the sensor suite design included state and environmental estimation and sensing. The sensors used included a stereo vision obstacle avoidance system, an above-water sonar system, and state sensors for position, attitude, and other necessary data (GPS, compass data, accelerometers, etc.).

Vehicle Lateral Control Using a Double Integrator Control Strategy

Researcher: Midshipman 1/C Charles E. George, USN
Adviser: Associate Professor Richard T. O'Brien, Jr.

The primary goal for this project was to become familiar with the concepts and theories necessary to implement a driver assistance steering controller. The research focused on two possible steering control methods: full state feedback and bang-bang control. This project built upon the preliminary design from Midshipman 1/C Steven Burns (Trident Scholar, Class of 2002). The aspect of control that required the most attention was the lateral position control. A mathematical model for the lateral motion of the RC vehicle was computed from experimental frequency and time response data. This model was compared with the analytical model derived by Midshipman Philip 1/C Hoblet (Trident scholar, Class of 2003). Using this model, bang-bang control methods developed for double integrator systems were applied to the design a steering controller. The performance of this controller was evaluated on the aforementioned model. An important aspect of the design was the effect of additional (non-integrator dynamics) on the controller. A hardware verification of the performance and robustness of the bang-bang controller was obtained using a ball-and-beam apparatus from Quanser, Incorporated.

Vision-Based Wave Sensing for High Speed Vessels

Researcher: Midshipman 1/C Jennifer L. Grob, USN
Advisers: Associate Professor Jennifer K. Waters (Naval Architecture and Ocean Engineering Department) and Assistant Professor Jenelle A. Piepmeier

During the EN495 course, Midshipman Grob tested the feasibility of vision-based wave sensing using a stereo vision system. A table-top wave tank was used to create small regular water waves, and surface plots were created using stereo imaging techniques. During the EN496 course, Midshipman Grob and Professors Waters and Piepmeier were able to collect extensive data at the Davidson Lab wave tank at the Stevens Institute of Technology in Hoboken, New Jersey. Tests were conducted to identify ideal lighting conditions, camera configuration, etc. A novel misting technique was used to overcome the challenges of imaging a transparent and reflective water surface. Tests were conducted for wavelengths of 1.1, 1.2, and 1.3 m with approximately 0.1m wave heights. The stereo information was analyzed in MATLAB. Spectral analysis of average wave surface data shows a strong correspondence with data collected from traditional wave gages.

Development of an Exercise Test Stand

Researcher: Midshipman 1/C Alan R. Van Reet, USN
Adviser: Assistant Professor Matthew G. Feemster
Sponsor: Bowman Scholar Program (BSP)

To evaluate control strategies for smart exercise systems, an electrically actuated exercise environment was developed. Specifically, a bicep/tricep exercise machine was augmented with a high torque/low speed DC motor for active resistance generation. A QNX based PC platform running the QMotor software served as the control implementation environment. The project also included the development and integration of the various sensors and power electronics.

Militarizing Commercial Automation for Integrated Power System Warship Command and Control

Researcher: Midshipman 1/C Alexis B. Wise, USN
Adviser: Assistant Professor Edwin L. Zivi
Sponsors: Bowman Scholar Program (BSP) and Office of Naval Research (ONR)

Automation technologies are essential to achieve future warship survivability despite increased threat and decreased manpower. Commercial technology can perform the tasks required for automation; however, they lack the dependability, system integrity, and fault tolerance a military platform requires in unpredictable battle environments. In this research, automation involved the transfer of functions from man to machine within the existing shipboard command and control structure. Viable commercial technologies exist for the engineering and damage control automation systems. The technical challenge was to extend commercial control technology to provide improve combat survivability. Emergent trends in naval combatant automation state-of-the-art were surveyed and discussed. Based on a DDG-51 manning baseline, specific engineering and damage control responsibilities were identified as automation candidates.

Small Watercraft Automation: Control

Researcher: Midshipman 1/C Gregory A. Woelfel, USN
Adviser: Associate Professor Bradley E. Bishop
Sponsor: Bowman Scholar Program (BSP)

This research project focused on the development of control hardware and software to allow automated testing of a surface vessel. The development of autonomous control suite, or test bed, for ship hull testing has the potential to eliminate many of the drawbacks of the U.S. Navy's ship design process. Whereas the combination of computational models and physical experiments is the best approach in the design and testing of new ship hull designs, both have drawbacks that make the design process incomplete and expensive, respectively. At their current stage of development, some Computational Fluid Dynamics models assume calm water, constant speed, and fixed-control surface settings. However, testing ship hull performance in dynamic and controlled environment is a time intensive process that involves a testing team, expensive wave generators, and large calibrated carriage machines to produce data that is often skewed because of operator error. Through an automated test bed, information can be delivered to the designer in less time, for less money, and with greater accuracy than any available simulation code and physical model combined. The developed system includes microprocessor control and data collection, wireless interface to a GUI, and obstacle avoidance.

Midshipman Design Projects

Morph Ball

Researchers: Midshipmen 1/C Albert F. Caluag and Hanna Lea L. Alerta, USN
Adviser: Lieutenant Commander Curtis S. Lindsay, USNR

UAV Design

Researchers: Midshipmen 1/C Aaron T. Allison, Justin C. Jimenez, Kristopher M. McAbee and Holly K. Siebel, USN
Adviser: Lieutenant Commander Michael J. Supko, USN

Swim Tracker 2004

Researchers: Midshipmen 1/C James P. Antoniono, Marshall T. Boyd and Christopher G. Hopkins, USN
Adviser: Lieutenant Colonel Randy P. Broussard, USAF

Whata Forker

Researchers: Midshipmen 1/C Jeremy D. Bartowitz, Cameron A. Douglas and Sean M. Meredith, USN
Adviser: Major Todd W. Ferry, USMC

Project FIDO
Researchers: Midshipmen 1/C Benjamin M. Bearman,
Michael J. Osterhaus and Xiao J. Sun, USN
Adviser: Lieutenant Colonel Randy P. Broussard, USAF

Environmental Weather Box
Researchers: Midshipmen 1/C Trevor A. Bingham and John M. Zahodne, USN
Adviser: Captain Allison D. Webster-Giddings, USN

Autonomous Room Security
Researchers: Midshipmen 1/C Robert C. Blackwood and Kurtis K. Wong, USN
Adviser: Lieutenant Benjamin F. Aton, USNR

Big Buzz
Researchers: Midshipmen 1/C Patrick J. Brandon, Michael J. Kunkel
and Daniel J. Moynihan, USN
Adviser: Lieutenant Commander Jennifer L. Nicholls, USN

Dark Rider
Researchers: Midshipmen 1/C Jeremiah T. Bright, Randall J. Leslie
and Erik N. Walker, USN
Adviser: Lieutenant Commander Curtis S. Lindsay, USNR

Variable Pitching Machine
Researchers: Midshipmen 1/C Nathan J. Browne, Keven M. Goering
and Joslyn M. Veney, USN
Adviser: Commander Timothy P. Tumelty, USN

Guitar Tuner
Researcher: Midshipman 1/C David S. Buck, USN
Adviser: Major Todd W. Ferry, USMC

Paintball Turret
Researcher: Midshipman 1/C Ronald F. Burris, USN
Adviser: Lieutenant Commander William S. Pendergrass, USN

Rowing Sentry
Researchers: Midshipmen 1/C Matthew A. Campbell, Michael C. Hockett,
Matthew J. Mathis and Ronald M. Stehlin, USN
Adviser: Lieutenant Commander Jennifer L. Nicholls, USN

Autonomous Chalk Dispenser
Researchers: Midshipmen 1/C Jeff G. Cliffe and Stephen V. Williams, USN
Adviser: Lieutenant Commander Jennifer L. Nicholls, USN

The Wanksta
Researchers: Midshipmen 1/C Jason C. Copeland, USN
Adviser: Lieutenant Commander Craig M. Payne, USNR

IPS Testbed
Researchers: Midshipmen 1/C Ryan J. Corcoran,
Si H. Kim and Alexis B. Wise, USN
Advisers: Lieutenant Commander Craig M. Payne, USNR
and Lieutenant Commander William S. Pendergrass, USN

T4
Researchers: Midshipmen 1/C Daniel C. Cuellar,
Reed P. Foster and Craig J. Richardson, USN
Adviser: Commander Juan A. Navarrete, USN

Semi-Autonomous Urban Combat Vehicle
Researchers: Midshipmen 1/C Brent E. Danielson,
Andrew S. Horah and Andrei G. Mititelu, USN
Adviser: Lieutenant Commander Michael J. Supko, USN

Player Guitar
Researchers: Midshipmen 1/C Sean R. Dougherty,
Jacob R. McIlvaine, Kyle C. Moore and Jared M. Wilhelm, USN
Adviser: Lieutenant Gene G. Severtson, USN

B.A.F.A.P
Researchers: Midshipmen 1/C Thomas J. Duff, Joel A. Gow,
Kellen L. Smith and Charles B. Zimmerman, USN
Adviser: Major Todd W. Ferry, USMC

Autonomous Boat
Researchers: Midshipmen 1/C Brian J. Ehrhardt and Gregory A. Woelfel, USN
Adviser: Lieutenant Commander Craig M. Payne, USNR

Swamp Assassinator
Researchers: Midshipmen 1/C Derek J. Elliot,
Joseph M. Foster and Matthew F. Rigler, USN
Adviser: Commander Juan A. Navarrete, USN

Bang-Bang Control of Double Integrator Systems
Researcher: Midshipman 1/C Charles E. George, USN
Adviser: Lieutenant Benjamin F. Aton, USNR

Systems Ball
Researchers: Midshipmen 1/C Thomas J. Gibbons and Matthew T. Israel, USN
Adviser: Commander Timothy P. Tumelty, USN

Active Roll Stabilization Systems
Researcher: Midshipman 1/C Brian D. Gordon, USN
Adviser: Captain Owen G. Thorp, III, USNR

Diver Heater
Researchers: Midshipmen 1/C Gabriel R. Grauke and Mark A. Knox, USN
Adviser: Commander Juan A. Navarrete, USN

UAV Threat Evasion System
Researchers: Midshipmen 1/C Matthew J. Hahn and Andrew M. Watts, USN
Adviser: Captain Gary D. Noble, USNR

Formation Flight
Researcher: Midshipman 1/C Jennifer L. Hammer, USN
Adviser: Captain Owen G. Thorp, III, USNR

Hands-Free Guitar
Researchers: Midshipmen 1/C Michael A. Heaphy and Davida D. Kirk, USN
Adviser: Major Todd W. Ferry, USMC

Helicopter UAV
Researchers: Midshipmen 1/C Lars C. Herman,
Michael R. Luebkert, Michael D. McMahon and Jacob Swanson, USN
Adviser: Captain Allison D. Webster-Giddings, USN

Environmental Weather Box
Researchers: Midshipmen 1/C Erich R. Hill and Trevor F. Sutton, USN
Adviser: Captain Allison D. Webster-Giddings, USN

Autonomous Rebounder
Researchers: Midshipmen 1/C Creighton K. Ho,
Alexander U. Lim and Joseph F. Walter, USN
Adviser: Commander Timothy P. Tumelty, USN

Robotic Golf Caddie 2004
Researchers: Midshipmen 1/C Jeffrey P. Hooke and Brian P. Storjohann, USN
Adviser: Lieutenant Gene G. Severtson, USN

The Dunkinator
Researchers: Midshipmen 1/C David A. Hunt and Luke R. Thompson, USN
Adviser: Lieutenant Commander William S. Pendergrass, USN

Systems Ball
Researchers: Midshipmen 1/C Robert D. Jenkins and John P. Kish, USN
Adviser: Lieutenant Commander Michael J. Supko, USN

Electronic Fuel Injection
Researchers: Midshipmen 1/C Alec M. Johnston and Christopher S. Josef, USN
Adviser: Commander Juan A. Navarrete, USN

New Hotness
Researchers: Midshipmen 1/C Jonathan W. Landers,
Matthew G. O'Connor and Matthew A. Slouka, USN
Adviser: Captain Gary D. Noble, USNR

First Robotics
Researchers: Midshipmen 1/C Noel A. Lewis and Travis W. Miller, USN
Adviser: Lieutenant Colonel Randy P. Broussard, USAF

Spininator
Researchers: Midshipmen 1/C Jacob C. Loeffler and Noah M. White, USN
Adviser: Lieutenant Benjamin F. Aton, USNR

Virtual Coxswain
Researchers: Midshipmen 1/C Paul M. March,
Jeffrey J. Morrison and Nicholas W. Rygiel, USN
Adviser: Captain Gary D. Noble, USNR

Shadow Boxer
Researchers: Midshipmen 1/C Tracy A. Martin,
Dimitry Rukhlin and Shawn D. Wilkinson, USN
Adviser: Captain Gary D. Noble, USNR

"Bobby" The Checker Playing Robot
Researchers: Midshipmen 1/C Michael C. Misch and Nathan J. Putzier, USN
Adviser: Lieutenant Colonel Randy P. Broussard, USAF

Collision Avoidance Vehicle
Researchers: Midshipmen 1/C Lenn B. Nakama and Neil J. Toohey, USN
Adviser: Lieutenant Commander William S. Pendergrass, USN

Autonomous Perimeter Defense System
Researchers: Midshipmen 1/C Aaron M. Ochalek and Erik R. Spalding, USN
Adviser: Lieutenant Colonel Randy P. Broussard, USAF

Wax Wizard
Researchers: Midshipmen 1/C Erica K. Porter and Kari A. Szewczyk, USN
Adviser: Lieutenant Gene G. Severtson, USN

The Range Eliminator
Researcher: Midshipman 1/C Eric M. Ranger, USN
Adviser: Major Todd W. Ferry, USMC

Weight-Free Weight Bench
Researcher: Midshipman 1/C Alan R. Van Reet, USN
Adviser: Lieutenant Commander Michael J. Supko, USN

Systems Ball
Researchers: Midshipmen 1/C Anthony G. Stranges and James R. Wilkins, USN
Adviser: Captain Owen G. Thorp, III, USNR

Publications

Journal (Refereed) Manuscripts

BISHOP, Bradley E., Associate Professor, "On the Application of Redundant Manipulator Techniques to the Control of Platoons of Autonomous Vehicles," *Institute for Electrical and Electronic Engineering* (*IEEE) Transactions on Systems, Man and Cybernetics Part A, Special Issue on Collective Intelligence*, September 2003, Vol. 33, Issue 5, pp. 608-615.

This paper discussed the parallelism between redundant manipulator control and the control of platoons (or swarms) of autonomous vehicles. We cast the platoon formation synthesis problem in an analogous manner to traditional redundancy resolution, and discuss techniques for real-time reactive path generation and control of the platoon. This fundamentally new method for casting the platoon problem offers guaranteed platoon-level performance with ``emergent'' element trajectories, reversing the typical methods used in behavior-based systems and offering a new paradigm for platoon formation synthesis and control. We demonstrated the efficacy of the proposed approach through simulation experiments.

PIEPMEIER, Jenelle A., Assistant Professor, KNOWLES, Kenneth A., Professor and BISHOP, Bradley E., Associate Professor, "Using MATLAB for Robotics Instruction," Computers in Education Journal (CoED), July-September 2003, Vol. XIII, No. 3, pp. 68-75.

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 and H. Lipkin, "Un-calibrated Eye-in-Hand Visual Servoing," *International Journal of Robotics Research - Special Issue on Visual Servoing,* October 2003, Vol. 22, No. 10/11, pp. 805-820.

This paper presented new un-calibrated control schemes for vision-guided robotic tracking of a moving target using a moving camera. These control methods were applied to an un-calibrated robotic system with eye-in-hand visual feedback. Without a prior knowledge of the robot's kinematic model or camera calibration, the system was 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 simulated and a variety of parameters were investigated with respect to performance. Simulation results suggested that a Gauss-Newton method utilizing a partitioned Broyden's method for model estimation provided the best steady-state tracking behavior.

Conference Proceedings

AVRAMOV-ZAMUROVIC, Svetlana, Associate Professor, Waltrip, Bryan and Koffman, Andrew, "Building a Very Precise Impedance Measurement Bridge," *American Society for Engineering Education (ASEE) 2003 Conference Proceedings*, Nashville, TN, June 2003. (CD-ROM)

At the United States Academy there are several engineering majors including Systems Engineering. This program offers excellent systems integration education. In particular the major concentrates on control of electrical,

computer and mechanical systems. Besides several tracks the students have the opportunity to independently research a field of interest. This is a great opportunity for teachers and students to go into more in-depth analysis. This paper described one such experiment in the field of metrology.

Very often engineering laboratories at the undergraduate schools are well equipped with power supplies, signal generators, oscilloscopes and possibly general-purpose multimeters. This set allowed teachers and students to set up test-beds for most of the basic electronics circuits studied in different engineering tracks. Modern instrumentation is in general user friendly and students like using digital oscilloscopes and signal generators. But very often students are not aware that there are two pieces of information necessary to establish a measurement result: numerical value of the measured quantity and the uncertainty with which that measurement was performed. In order to achieve very high measurement accuracy more complex measurement systems have to be developed. This paper described the process of analyzing a measurement.

BISHOP, Bradlley E., Associate Professor, PIEPMEIER, Jenelle A., Assistant Professor, PIPER, George E., Associate Professor, KNOWLES, Kenneth A., Professor, Ho, Kim, and HUDOCK, Bryan M. (Trident Scholar, Class of 2003), "The Use of Low-Cost RC Servos in a Robotics Curriculum," Accessible Hands-on Artificial Intelligence and Robotics Education: Papers from 2004 American Association for Artificial Intelligence (AAAI) Spring Symposium**,** Palo Alto, CA, April 2004, pp. 52–57.

Small hobby servo motors designed for remote controlled (RC) model cars and airplanes are commonly used actuators by robotic hobbyists. They also serve as actuation for a number of commercially available robotic kits. These inexpensive RC servo motors can serve as a useful low-cost alternative actuation method for student projects and laboratory investigations. This paper discussed two laboratory assignments and two independent student research projects that have used this type of actuation.

BROUSSARD, Randy P., Lt Col (USAF) and Assistant Professor and PIEPMEIER, Jenelle A., Assistant Professor, "Undergraduate Computer Vision Curriculum to Complement a Robotics Program," *American Society for Engineering Education (ASEE) Annual Conference Proceedings*, Salt Lake City, UT, June 2004. (CD-ROM)

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

DWAN, Terrence E., Professor, DEMOYER, Robert, Professor, WICK, Carl E., Professor and PIPER, George E., Associate Professor, "Systems Engineering at the U.S. Naval Academy," *2004 American Society for Engineering Education (ASEE) Annual Conference Proceedings*, Salt Lake City, UT, June 2004. (CD-ROM)

This paper described the current curriculum of the Systems Engineering Department at the U. S. Naval Academy in detail. We showed how our program not only serves the needs of each military graduate and meets the objectives and requirements of an ABET accredited program, but also why this curriculum has become one of the most popular and successful undergraduate programs at the U. S. Naval Academy.

ESPOSITO, Joel M., Assistant Professor, "Randomized Test Case Generation for Hybrid Systems: Metric Selection", *Institute for Electrical and Electronic Engineering* (*IEEE) Southeastern Symposium on Systems Theory*, Atlanta, GA, March 2004, pp. 236-240.

In this project, we developed a randomized approach to test generation for hybrid systems, and control systems in general, using techniques from robotic path planning which have proved successful in solving high dimensional

nonlinear problems. A critical component of the proposed algorithm is the choice of ``metric" -- how one decides the closeness of two states -- which is nontrivial in the hybrid state space. In this paper we introduced four metrics for hybrid systems; and benchmark the algorithm using each of these metrics on a popular example problem from the literature and compared the impact of metric choice on computational efficiency.

ESPOSITO, Joel M., Assistant Professor, FEEMSTER, Matthew G., Assistant Professor and WATKINS, John M., Associate Professor, "Role of a MATLAB Real-Time Hardware Interface Within a Systems Modeling Course," *Proceedings of the American Society for Engineering Education (ASEE)*, Salt Lake City, UT, June 2004. (CD-ROM)

In an effort to offer students a more tangible understanding of system modeling concepts, the Quanser/MATLAB hardware interface has been employed at USNA in the laboratory setting of an undergraduate modeling course. Specifically, the SIMULINK-based interface has enabled students to model various physical systems and then compare the system performance predicted by their simulation to the actual response of the physical system. In this paper, an actual case study performed by the midshipmen utilizing the Quanser interface system with a rigid-link, flexible-joint robotic manipulator is presented.

Fang, Y., FEEMSTER, Matthew G., Assistant Professor and Dawson, D., "Nonlinear Disturbance Rejection for Magnetic Levitation Systems," *Proceedings of the Institute for Electrical and Electronic Engineering (IEEE) International Symposium on Intelligent Control*, Houston, TX, October 2003, pp. 58-62.

In this paper, a position regulation control strategy was developed for a magnetic levitation system operating in the presence of a bounded, nonlinear, periodic disturbance. The proposed controller utilized a saturated control force input in conjunction with a learning based disturbance estimator to asymptotically 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). In addition, the control development only requires the disturbance input to be bounded and periodic in nature.

FEEMSTER, Matthew G., Assistant Professor, "An Adaptive Cruise Control System for an Electric Vehicle," *20th International Electric Vehicle Symposium and Exposition Proceedings*, Long Beach, CA, November 2003. (CD-ROM)

The modular design approach of a newly constructed multiphase permanent magnet motor (PMM) has eased the development of an adaptive speed control strategy. The motor's uniqueness lies in the fact that the electromagnetic cores are segmented to not only minimize the active mass, but also to reduce the core losses of the motor. As a result, the requirement for embedded correction algorithms for the compensation of cogging torque within the motor have been eliminated, thus allowing more focus to be placed on strategies aimed at maximizing active torque generation. Therefore, the focus of this paper was on the design of control strategy that optimizes energy usage under various loading conditions. Application to electric vehicles was intended.

GEORGE, Charles E., Midshipman 1/C, USN, and O'BRIEN, Richard T., Jr., Associate Professor, "Vehicle Lateral Control Using a Double Integrator Control Strategy," *Proceedings of Institute for Electrical and Electronic Engineering (IEEE) Southeastern Symposium on Systems Theory*, Atlanta, GA, March 2004, pp. 398-400.

In this paper, a bang-bang control algorithm developed for double integrator systems was applied to the problem of automated vehicle steering control. This research is part of an on-going project on vehicle control using scale-model vehicle simulator. The controller uses pre-determined, piecewise constant control signals to shape the lateral position and yaw angle responses. Simulation results demonstrated that the proposed control algorithm maintains acceptable performance despite the un-modeled dynamics.

GROB, Jennifer L., Midshipman 1/C, USN, WATERS, Jennifer, Associate Professor, and PIEPMEIER, Jenelle A., Assistant Professor, "Vision-Based Wave Sensing for High Speed Vessels," *Proceedings of the Institute for Electrical and Electronic Engineering (IEEE) Southeastern Symposium on Systems Theory*, Atlanta, GA, March 2004, pp. 290-293.

Vision-based water wave sensing is a technique that can be used to create a pro-active ride control system for high-speed marine vessels. This paper discussed a vision-based wave sensing approach that is able to determine pertinent wave characteristics such as slope, height, and frequency. The initial goal of this project is to develop a system that can acquire an image of a wave surface and accurately measure its characteristics. System equipment includes a stereo vision system from Pt. Grey Research. The stereo vision system is capable of producing point cloud images. MATLAB is used to analyze the recorded data and compute critical information, such as local maximums and minimums, for examining wave characteristics.

HO, Kin Leong, 1/C Midshipman, USN, PIPER, George E., Associate Professor, WATKINS, John M., Associate Professor, and PIEPMEIER, Jenelle A., Assistant Professor, "Robotic Testbed for Simulating Spacecraft Relative Motion," *Proceedings of the 2003 NASA Flight Mechanics Symposium*, Greenbelt, MD, October 2003. (CD-ROM)

There has been a growing interest within the United States space community to develop autonomous rendezvous and capture (ARC) capability on unmanned space vehicles. Such technology will enable the realization of several high-priority missions such as the autonomous replenishment of the International Space Station, and on-orbit refueling and maintenance of satellites. There is, however, an inherent high cost associated with the research, development, and testing of autonomous rendezvous and capture in a space environment. Consequently, a robotic platform that is capable of accurately simulating spacecraft dynamic motion will enable researchers to conduct their studies in a low cost environment in which they can afford to implement their control strategies without inhibitions. There are several on-going projects that use robotic platforms to simulate relative spacecraft motion in a plane. However, most of these platforms are highly sophisticated and complex making them cost prohibitive for many institutions.

This paper presented the development of a fairly inexpensive test facility that used mobile robotic platforms to simulate relative planar motion for evaluating ARC control system logic and sensing strategies. The simulator consisted of a simulation computer, two mobile robot platforms, and a vision system. The simulation computer computed the dynamic behavior of the space vehicles in the space environment. The robot platforms representing the space vehicles moved in accordance to the simulated space vehicle's behavior. The mobile robotic platforms used in the simulator were based on the Palm Pilot Robot that was designed by the Carnegie Mellon Robotics Institute. The robotic platforms used three omni-directional wheels in a triangular arrangement that could drive the platform in any direction with independent control of rotation, meaning it moved holonomically in the plane. The holonomic motion control distinguished this robotic platform from most common mobile robots.

HUDOCK, Bryan M. (Trident Scholar, Class of 2003), BISHOP, Bradley E., Associate Professor and CRABBE, Frederick. L., Assistant Professor (Computer Science Department), "On the Development of a Novel Urban Search and Rescue Robot," Proceedings of the 36th Annual Southeastern Symposium on Systems Theory, March 2004, pp. 451-455.

This paper proposed the development of a novel robotic platform for Urban Search and Rescue (USAR) efforts. The main facets of this work involved the design and construction of a new robot morphology and a physical simulation to be used for developing controllers for semi-autonomous (supervisory) operation.

KIRIAKIDIS, Kiriakos, Associate Professor, "On the Expansion of Nonlinear Models Using Bell-Shaped Basic Functions," *Proceeding of the American Society for Mechanical Engineers (ASME) International Mechanical Engineering Congress*, Washington, DC, November 2003. (CD-ROM)

We proposed a method that approximated any nonlinear model, without regard to complexity, by minimizing its distance from a rich model set. The method produced, potentially through an automated procedure, the approximation of the nonlinear dynamics in the form of a finite expansion associated with certain basic functions and provided an upper bound on the approximation error.

Kellogg, James, Bovais, Christopher, Foch, Richard, Cylinder, David, Ramamurti, Ravi, Sandberg, William, Gardner, John, Srull, Donald, PIPER, George, E., Associate Professor, Vaiana, Peter, and Kahn, Aaron, "Development and Testing of Unconventional Micro Air Vehicle Configurations," *Proceedings of the 2nd American Institute of Aeronautics and Astronautics (AIAA) Unmanned Unlimited Systems, Technologies, and Operations (Aerospace, Land, and Sea) Conference*, San Diego, CA, September 2003. (CD-ROM)

The Naval Research Laboratory (NRL) developed a group of micro air vehicle (MAV) concepts intended for operation in urban or other confined environments. Primary flight requirements for these MAVs are low speed maneuverability, vertical or near vertical takeoff and landing, the potential for hovering, and compatibility with ground operation as a "perched" sensor platform. The additional requirement for such MAVs to be small enough (wingspans of less than 150 mm) to operate unobtrusively has focused attention on flapping foil propulsion and other unconventional configurations. In the low Reynolds number (2,000 _ Re _ 30,000) and low speed (2-5 m/s) regimes applicable to such tiny aircraft, airfoil performance degradation significantly reduces propeller efficiency as size decreases. Flapping wings can be dynamically advantageous for propulsion under these conditions. While many flapping wing vehicles such as ornithopters attempt to mimic the flight of birds or insects, it is possible to use flapping foil propulsion in ways that are inspired by biological flight but do not copy it directly. "Aerial swimming" vehicles use a flapping wing that resembles a boat's sail with the mast running horizontally, driven by a central oscillating beam. The wing's camber reversed on each half cycle. Three configurations have flown successfully: a vehicle with a fixed forward wing and a rear flapping wing; a tandem fixed-wing design with a third flapping wing that claps down atop the rear fixed surface on each stroke; and a vehicle with tandem pairs of biplane configured flapping wings, in which each pair moves in opposition so as to alternately clap together and separate. This latter vehicle, which did not employ fixed lifting surfaces, has the advantage of being dynamically balanced in flight so that its center of mass is not forced to oscillate vertically by the flapping action. In addition, development is underway on a stop-rotor hybrid vehicle. This employs a pair of single-blade, rotary/fixed wing panels, attached at their roots to separate coaxial shafts. For low-speed flight the wing panels are driven as contra-rotating rotor blades for lift. A pusher propeller provided primary thrust, and control surfaces in the propeller wash provide pitch, yaw, and roll control. In fixed wing flight the wing panels are stopped opposite each other to become a conventional wing. This configuration eliminates the airflow reversal over the wing that occurs upon conversion in other stop-rotor designs. Developmental models of this vehicle have flown successfully in both fixed and rotary wing modes. Computational fluid dynamics (CFD) studies of these vehicles are underway to optimize propulsion efficiency and flight control techniques. In this paper, descriptions, videos, CFD simulation results, and flying models of several novel unmanned air vehicles were presented.

O'BRIEN, Richard T., Jr., Associate Professor and KIRIAKIDIS, Kiriakos, Associate Professor, "Convergence and Performance in H-Infinity-Based Parameter Identification," *Proceedings of the IFAC Symposium on Robust Control Design*, Milan, Italy, June 2003. (CD-ROM)

This paper addresses the problem of identifying the parameters of linear state-space models using gain criterion. The present work contributed in two areas whereupon the counterpart of minimization in nonlinear systems needs improvement. First, the parameter estimator under consideration, which meets the aforementioned criterion within a first-order approximation, produces recursive estimates that are close to the off-line estimates for a large number of data. Second, a method to update the bound on the disturbance attenuation is proposed and shown to enhance the performance of the estimator. A numerical example demonstrated the results by solving the direction-of-arrival estimation problem associated with an array of antenna elements.

O'BRIEN, Richard T., Jr., Associate Professor and KIRIAKIDIS, Kiriakos, Associate Professor, "Single-Snapshot Robust Direction Finding," *Proceeding of the International Conference on Acoustics, Speech, and Signal Processing*, Montreal, Canada, May 2004. (CD-ROM)

This paper presented a novel approach to estimate the directions 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 based on worst-case gain minimization. The performance of the new approach was evaluated by simulating the estimation algorithm for a linear array and comparing its performance to that of an existing single-snapshot algorithm.

O'BRIEN, Richard T., Jr., Associate Professor, "A Bang-Bang, Disturbance Rejection Algorithm for Double Integrator Systems," *Proceedings of Institute for Electrical and Electronic Engineering (IEEE) Southeastern Symposium on Systems Theory*, Atlanta, GA, March 2004, pp. 84-87.

An existing sampled-data control algorithm for double integrator systems with pre-determined inter-sample behavior is generalized to incorporate disturbance rejection in addition to command tracking. The proposed control system comprises an inner velocity control loop and an outer position control loop. A discrete-time compensator is used to regulate velocity and reject step disturbance in acceleration due to forces or moments on the system. The outer loop produced a pre-determined, piecewise constant (bang-bang) signal proportional to the position tracking error that defined the desired inter-sample position and velocity behavior. Simulation results of the disturbance rejection performance were presented.

O'BRIEN, Richard T., Jr., Associate Professor and WATKINS, John M., Associate Professor, "A Unified Approach for Teaching Root Locus and Bode Compensator Design," *Proceedings of the 2003 American Control Conference*, Denver, CO, June 2003, pp. 1506-1511.

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 the textbook. As an alternative, the authors of this paper proposed 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 was 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) were developed from this simple PD design. Procedures for rate feedback, lag and PI-lead (practical PID) compensators were also developed using this approach. The proposed Bode design procedures were 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 was presented.

PATTERSON, Sean M., (Trident Scholar, Class of 2003), KNOWLES, Kenneth A., Professor, and BISHOP, Bradley E., Associate Professor, "Toward Magnetically Coupled 2-D Reconfigurable Modular Robots," Proceedings of Institute for Electrical and Electronic Engineering (IEEE) International Conference on Robotics and Automation, New Orleans, LA, April 2004, pp. 2900-2905.

This paper presented the design of a robotic module that is the building block for a magnetically-coupled reconfigurable robot network. The developed module has on-board computation, IR communication and integrated power. The development of this modular network and the associated reconfiguration methodology was motivated by the premise that magnetic latching is much more plausible than physical latching as scale decreases to the micro- and nano- levels.

PIEPMEIER, Jenelle A., Assistant Professor, McMurray, G.V. and Lipkin, H. "Un-calibrated Dynamic Visual Servoing," *Proceedings of Institute for Electrical and Electronic Engineering (IEEE) Transactions on Robotics and Automation*, Atlanta, GA, February 2004, Vol. 20, No.1, pp. 143-148.

A dynamic quasi-Newton method for un-calibrated, vision-guided robotic tracking control with fixed imaging was developed and demonstrated. This method does not require calibrated kinematic and camera models. Robotic control was achieved at each step through minimizing a nonlinear objective function by taking quasi-Newton steps and estimating the composite Jacobian at each step. The Jacobian was estimated using a dynamic recursive least squares algorithm. Experimental results demonstrated the validity of this approach.

PIPER, George E., Associate Professor, WATKINS, John M., Associate Professor, and Leitner, Jesse, "On the Impact of Cross-Link Delays on Spacecraft Formation Control," *Proceedings of the 2003 American Institute of Aeronautics and Astronautics (AIAA) Guidance, Navigation, and Control Conference*, Austin, TX, August 2003. (CD-ROM)

In this paper, the ability for tight formation control in the presence of communication and measurement delays was investigated. The paper discussed cross-link requirements for formation control and compares centralized

and decentralized control strategies. A simple two degree-of-freedom model with communication delays was introduced for analysis. A typical approach for systems with small time delays was to base the design on a nominal system model that did not contain the time-delays. The limitations of this approach on stability and closed-loop bandwidth were discussed. Finally, the time delay was considered in the design of state-feedback with integral feedback controllers. The effects of the time-delay on stability, stability margins, and bandwidth were investigated. An example illustrating these effects was presented.

WATKINS, John M., Associate Professor, and O'BRIEN, Richard T., Jr., Associate Professor, "A Novel Approach to a Control Systems Laboratory," *Proceeding of the American Society for Mechanical Engineers (ASME) International Mechanical Engineering Conference and Exposition*, Washington, D.C., November 2003. (CD-ROM)

In controls education today, a significant gap exists between the material covered in the typical undergraduate classroom and the skills that students need to be practicing control system engineers. In order to help bridge this gap, a control systems laboratory was developed in the Systems Engineering Department at the United States Naval Academy with the following design objectives. The first objective was to provide the students the opportunity to apply control theory to physical systems. The second objective was to develop labs where each student works through the complete control system design process. The third objective was to increase the students' exposure to sampled-data control. The paper begins with a discussion of the Quanser rapid control prototype development system and laboratory experiments. Modeling and system identification were discussed next. Key areas that were emphasized include the use of a dynamic signal analyzer for frequency domain identification and the identification of Coulomb friction for simulation purposes. A unified approach for root locus and Bode design that is used through out the course was discussed next. Finally, analog and digital controller implementations were discussed.

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 a 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 was 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 was motivated by the formation flying challenge. In this paper, the ability for tight formation control in the presence of communication and measurement delays was 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 was introduced for analysis. A typical approach for systems with small time-delays was to base the design on a nominal system model that did not contain the time-delays. The limitations of this approach on stability and closed-loop bandwidth were 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.

WICK, Carl E., Professor, AVRAMOV-ZAMUROVIC, Svetlana, Associate Professor and Lyle, James, "Hard Disk Interface Used in Computer Forensic Science," *Proceedings of the Instrumentation, Measurement and Technology Conference (IMTC) 2004 Instrumentation and Measurement Technology Conference*, Como, Italy, May 2004. (CD-ROM)

This paper discussed a project that is related to the National Institute of Standards and Technology (NIST) development of standard methods for testing disk imaging tools. The goal of the project was to enhance current software-intensive tool tests by providing a hardware-oriented mechanism for simulating disk drive faults. This new system was significant because knowing the behavior of computer forensics tools operating in the presence of I/O errors was critical to a complete evaluation of disk imaging tools, and it is difficult to simulate hardware errors accurately with software alone.

Yuan, G., Shiei, M. and FEEMSTER, Matthew G., Assistant Professor, "Per-Phase D-Q Model for Multiphase PM Motors With Segmented Magnetic Paths," *Electric Machines Technology Symposium*, Philadelphia, PA, January 2004. (CD-ROM)

A per-phase d-q model was discussed for a unique design of multiphase permanent magnet synchronous motors (PMSM). The uniqueness lies in the fact that the magnetic path for each phase was isolated from those of its neighboring phases. The physical segmentation of the electromagnetic cores on the stator not only minimized the active mass and reduced core losses, but also presented a simpler motor control structure. Two optimization objectives were thus formulated based on the per-phase d-q model. The first objective was to maximize the total torque output of the motor for a given voltage and current rating while the second objective was to maximize the overall torque-per-ampere rating.

Patents

Maslov, Boris A., Soghomonian, Zareh, and FEEMSTER, Matthew G., Assistant Professor, U.S. Patent No: 6,727,668, "Precision Brushless Motor Control Utilizing Independent Phase Parameters," awarded 27April 2004.

A control system for a multiphase permanent magnet motor compensates for physical variations among individual motor phase circuit elements. The control system successively develops a control voltage for switched energization of the motor phase windings that is closely matched with particular parameters of the corresponding windings. The system can be applied to a motor in which each stator phase component comprises a ferromagnetic isolated stator electromagnet, the electromagnet core elements being separated from direct contact with each other and formed with separate phase windings. A digital signal processor may be utilized that applies an algorithm incorporating the parameters as constant values, the parameters for a particular phase being accessed for generating the appropriate control signals for energizing that phase.

Technical Reports

BISHOP, Bradley E. Associate Professor, PIEPMEIER, Jenelle A., Assistant Professor, PIPER, George, E., Associate Professor, KNOWLES, Kenneth A., Professor, HO, Kinleong, Midshipman 1/C, USN and HUDOCK, Bryan M. (Trident Scholar, Class of 2003), "The Use of Low-Cost RC Servos in a Robotics Curriculum," *American Association for Artificial Intelligence* (*AAAI) Spring Symposium: Accessible Hands-on Artificial Intelligence and Robotics Education*, Technical Report SS-04-01, Palo Alto, CA, March 2004, pp. 52-56.

Small hobby servo motors designed for remote controlled (RC) model cars and airplanes are commonly used actuators by robotic hobbyists. They also serve as actuation for a number of commercially available robotic kits. These inexpensive RC servo motors can serve as a useful low-cost alternative actuation method for student projects and laboratory investigations. This paper discussed two laboratory assignments and two independent student research projects that used this type of actuation.

Magazines

PIEPMEIER, J. A., Assistant Professor, BISHOP, B. E., Associate Professor and KNOWLES, K. A., Professor, "Modern Robotics Engineering Education," *Institute of Electrical and Electronics Engineers (IEEE) Robotics and Automation Magazine*, Vol. 10, Issue 2, June 2003, pp. 33-37.

In this paper we discussed the three basic principles of robotics education in the modern environment, and contrast 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. We conjecture that insight cannot be gained from textbooks and laboratory experiments alone, as these tend to focus on merely academic rather than global and societal issues. We presented herein a discussion of the techniques used at the United States Naval Academy (USNA) to inform, educate and motivate students in the field of robotics.

Presentations at Professional Meetings and Conferences

BISHOP, Bradley E., Associate Professor, EHRHARDT, Brian J., Midshipman 1/C, USN and WOELFEL, Gregory A., Midshipman 1/C, USN, "Planning Craft Test Bed Automation," Meeting of the Atlantic Center for the Innovative Design of Small Ships, Annapolis, MD, November 2003.

BISHOP, Bradley E., Associate Professor, EHRHARDT, Brian J., Midshipman 1/C, USN and WOELFEL, Gregory A., Midshipman 1/C, USN, "Development of an Autonomous Planning Watercraft Test Bed," 36th Annual Southeastern Symposium on Systems Theory, Atlanta, GA, March 2004.

BISHOP, Bradley E., Associate Professor, PIEPMEIER, Jenelle A., Assistant Professor, PIPER, George E., Associate Professor, KNOWLES, Kenneth A., Professor, HO, Kim L., Midshipman 1/C, USN and HUDOCK, Bryan M. (Trident Scholar, Class of 2003), "The Use of Low-Cost RC Servos in a Robotics Curriculum," Accessible Hands-on Artificial Intelligence and Robotics Education, 2004 American Association for Artificial Intelligence (AAAI) Spring Symposium, Stanford, CA, April 2004.

BROUSSARD, Randy P., Lt Col (USAF) and Assistant Professor, and PEIPMEIER, Jenelle A., Assistant Professor, "Undergraduate Computer Vision Curriculum to Complement a Robotics Program," American Society for Engineering Education (ASEE) Annual Conference, Salt Lake City, UT, June 2004.

DWAN, Terrance E., Professor, (co-author), "Systems Engineering at the U.S. Naval Academy," American Society for Engineering Education (ASEE) Annual Conference, Salt Lake City, UT, June 2004.

ESPOSITO, Joel M., Assistant Professor, "New Directions in Testing Hybrid Control Systems," Workshop on Randomized Methods in Control and Planning, Philadelphia, PA, March 2004.

ESPOSITO, Joel M., Assistant Professor, "Randomized Test Case Generation for Hybrid Systems: Metric Selection," Institute for Electrical and Electronic Engineering (IEEE) Southeastern Symposium on Systems Theory, Atlanta, GA, March 2004.

ESPOSITO, Joel M., Assistant Professor, FEEMSTER, Matthew G., Assistant Professor and WATKINS, John M., Associate Professor, "Role of a MATLAB Real-time Hardware Interface Within a Systems Modeling Course," American Society for Engineering Education (ASEE) Annual Conference, Salt Lake City, UT, June 2004.

FEEMSTER, Matthew G., Assistant Professor, "Nonlinear Disturbance Rejection for Magnetic Levitation Systems," Institute for Electrical and Electronic Engineering (IEEE) International Symposium on Intelligent Control, Houston, TX, October 2003.

FEEMSTER, Matthew G., Assistant Professor, "Development of an Exercise Test Stand," Institute for Electrical and Electronic Engineering (IEEE) Southeastern Symposium on Systems Theory, Atlanta, GA, March 2004.

HUDOCK, Bryan M. (Trident Scholar, Class of 2003), BISHOP, Bradley E., Associate Professor, and CRABBE, F. L., Assistant Professor (Computer Science Department), "On the Development of a Novel Urban Search and Rescue Robot," Institute for Electrical and Electronic Engineering (IEEE) Southeastern Symposium on Systems Theory Atlanta, GA, March 2004.

KIRIAKIDIS, Kiriakos, Associate Professor, "Convergence and Performance in H-Infinity-Based Parameter Identification," International Federation of Automatic Control (IFAC) Symposium on Robust Control Design, Milan, Italy, June 2003.

KIRIAKIDIS, Kiriakos, Associate Professor, "On the Expansion of Nonlinear Models Using Bell-Shaped Basis Functions," American Society of Mechanical Engineers (ASME) International Mechanical Engineering Congress, Washington, D.C., November 2003.

KIRIAKIDIS, Kiriakos, Associate Professor, "Single-Snapshot Robust Direction Finding," International Conference on Acoustics, Speech, and Signal Processing, Montreal, Canada, May 2004.

KIRIAKIDIS, Kiriakos, Associate Professor, "H-Infinity-Based D & T," Office of Naval Research Maritime Sensing Program Review, Newport, RI, May 2004.

KNOWLES, Kenneth, A., Professor, and Brown, Dave, "U. S. Naval Academy 2002-2003 Helicopter Surveillance System," 2003 Naval-Industry Research & Development Partnership Conference, Washington, D.C., August 2003.

O'BRIEN, Richard T., Jr., Associate Professor, "An H-Infinity-Based Detection and Tracking Method for Underwater Sensor Systems," Office of Naval Research Sponsor Review, Arlington, VA, September 2003.

O'BRIEN, Richard T., Jr., Associate Professor, "A Bang-Bang, Disturbance Rejection Algorithm for Double Integrator Systems," Institute for Electrical and Electronic Engineering (IEEE) Southeastern Symposium on System Theory, Atlanta, GA, March 2004.

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