Computer Science Department

Professor Patrick R. Harrison
Chair

During the 2002-2003 academic year, the Computer Science Department faculty did significant research in the areas of software engineering, robotics, computer algebra, intelligent tutoring and advanced distributed computing. A number of independent research projects were conducted. Midshipmen also participated in summer internships at the Naval Research Laboratories and at the Defense Information Systems Agency. Two new Trident projects were completed, including one on robotics and the other on scheduling. The Computer Science Department faculty continues to attract grant money and research opportunities from both government and commercial sources. This year the department developed a prototype CAVE to support research in virtual reality and 3-dimentional graphics and continued development of the advanced Information Assurance lab to support research in information security.

Sponsored Research

Computing with Semi-Algebraic Sets Using Cylindrical Algebraic Decomposition

Researcher: Assistant Professor Christopher W. Brown
Sponsors: Office of Naval Research (ONR) and Naval Academy Research Council (NARC)

This project was part of the PI's ongoing program of devising algorithms and creating software capable of computing symbolically with semi-algebraic sets for problems arising in practice. Current methods are capable of solving such problems in theory, but in practice their time and space requirements are prohibitive for real applications. This project focused on improving algorithms and software based on Cylindrical Algebraic Decomposition (CAD). Its three primary goals were: 1) improving the availability, quality and documentation of CAD-based software, 2) devising improved methods of CAD construction for special cases that are of interest to potential application communities, and 3) exploring new applications of CAD.

This summer's work resulted in the release of the QEPCAD B system for computing with semi-algebraic sets via CAD. A paper outlining this system is under review for the ACM SIGSAM Bulletin, and the PI has been invited to provide a paper on the system for a special issue of the Journal of the Japan Society for Symbolic and Algebraic Computation on quantifier elimination. The PI submitted a proposal to the National Science Foundation in November requesting three years funding to continue with this project. The Director of the Graphics, Symbolic and Geometric Computation Program at NSF recommended that the project be funded; the NSF Division of Grants and Agreements has agreed to fund it.

Imitation Learning of Goal Sequences in Mobile Robots

Researcher: Assistant Professor Frederick L. Crabbe, IV
Sponsor: Office of Naval Research (ONR)

Most studies of imitation learning in robots or other artificial agents concentrate on enabling a robot to learn to repeat individual low-level actions made by a teaching agent. The objective of this project was to expand imitation learning to enable a student robot to learn to identify and perform sequences of high-level sub-goals, each made up of multiple low-level actions. For example, a student agent would follow a teacher agent as the teacher performs a task in order to learn to perform that same task. When the teacher completes each sub-goal in the sequence, the student learns the purpose of each sub-goal as well as when to perform it in the sequence. Currently, work is focusing on enabling a learning robot to segment the stream of motor commands performed by the teaching robot into conglomerate actions. The learning robot uses Bayesian techniques to determine the relative probabilities of various motions in order to determine if one action has ended and another has begun.

Enterprise Computing with NET, ASP+, C# and SOAP

Researcher: Professor Patrick R. Harrison
Sponsor: Microsoft

The purpose of this research was the development and testing of concepts for Visual Studio NET and next generation programming environments, tools, help systems and debuggers. This is ongoing and proprietary. This has produced a set of ASP.NET materials being distributed internationally.

VEHELO

Researchers: Rudolph Darken, Ph.D., Commander Joseph Sullivan, USN
and Major Mark J. Lennerton, USMC
Sponsor: Office of Naval Research (ONR), Navy Modeling and Simulation Office (N61M)

Virtual Environment Helicopter (VEHELO) delves into developing compelling task oriented virtual environments for use as deployable military trainers. This research collaborated with the Virtual Technologies and Environments (VIRTE) program which was sponsored by ONR. VIRTE is an expansive program touching all aspects of expeditionary warfare. It involves the use of virtual environment technologies for training, mission rehearsal, and other mission critical tasks. It involves the construction of these systems as well as analysis and experimentation. Its goals are set extremely high. Under the VIRTE umbrella, VEHELO considers the viability of VE networking, mission rehearsal systems, training transfer, as well as other human factors issues involved in these technologies.

High Energy Laser Weapons: Modeling and Simulation (Phase II, Modeling Development)

Researcher: Associate Professor Donald M. Needham
Sponsor: The High-Energy Laser Joint Technology Office

Development of one or more end-to-end simulations of laser system performance and effectiveness is fundamental to the goals of the High Energy Laser Joint Technology Office's (JTO) modeling and simulation (M&S) program. One such simulation prospective follows the physics and engineering of a ship's energy starting with energy conversion from the ship's fuel through electrical power generation, electrical generation of laser light, beam transport, etc, and ending with target damage assessment. A fundamental step, proposed by this research, in the process of developing a domain-reusable, end-to-end high energy laser simulation, was to examine an existing model, and focus on the identification of a software system architecture designed to support the inclusion of modeling components needed for the various portions of an end-to-end simulation. The steps in this process include acquiring a suitable high energy laser model, and developing an architecture that isolates and minimizes couplings between the software components that implement the model. Analysis of the resulting architecture focuses on increasing its potential for domain-specific reuse so that suitable models for the remaining portions of the end-to-end simulation can be smoothly integrated. Additionally, this work is expected to provide guidance to high energy laser modelers on developing software components that implement their models so as to ease integration of their models within an end-to-end simulation.

The Andes Project

Researcher: Professor Kay G. Schulze
Sponsor: Office of Naval Research (ONR)

Classical physics is a prerequisite for virtually all university-level study of science and technology, yet is notoriously difficult for students to learn. The Andes project is an intelligent tutoring system that is intended for use as a "homework helper" for students taking Physics. This year the project concentrated on modeling electricity and magnetism problems and improving the help system.

Independent Research

PCSAT2 User-Interface Design

Researcher: Assistant Professor David J. Stahl, Jr.

This project involved the design and implementation of Microsoft Windows-based user interface software for deployment aboard a future NASA Space Shuttle mission. The software allows astronauts to remotely operate the USNA PCSAT2 communications device deployed as a Materials International Space Station Experiment (MISSE). PCSAT2 is a satellite communications system operated in coordination with the international Amateur Radio on the International Space Station (ARISS) team. Initial software implementation is complete and under project manager review.

Software Chroma-keying for Augmented Reality Applications

Researcher: Assistant Professor David J. Stahl, Jr.

This project investigated the feasibility of merging a real-time video stream with a software rendered stream using chroma-keying, for output to a head-mounted virtual environment display. The intent was to eliminate the need for high-cost hardware chroma-key mixing devices, by utilizing the image processing capabilities of OpenGL on low-cost graphics hardware. The results of this project have direct application to current research in augmented reality being conducted within the Computer Science Department by Major Mark Lennerton, USMC. This project is currently in requirements analysis.

A Particle System Method for Quantifying Cardiac Ejection Fraction

Researcher: Assistant Professor David J. Stahl, Jr.

This research first required porting an existing physically-based modeling, visualization and physical simulation environment previously developed by the PI, from its current UNIX/SGI implementation to a Windows/PC implementation. Second, an existing volumetric model of a human left ventricle was improved to permit blood pool introduction and ejection. This requires data conversion and modification to produce an anatomically correct myocardium model with a left atrium, aorta, and associated valves suitable for use in the simulation system. Third, the particle system model will be revised to allow temporally changing internal model representations to permit the modeling of cardiac valves that open and close. Finally, simulations will be run to demonstrate the ability to measure cardiac ejection fraction with this approach. This effort is presently in the software porting stage.

Object-Oriented Method for Interoperability

Researchers: Captain Paul E. Young, USN
and Lieutenant George M. Lawler, USN (Naval Postgraduate School)

The research focused on developing an enhancement to the model used in the Object Oriented Method for Interoperability (OOMI), as developed in the PI's dissertation. The objective of the research was to enable the OOMI to be used in a distributed environment as well as to provide the description of a distributed software system facility to facilitate the collaborative construction of a Federation Interoperability Object Model (FIOM) for a system-of-systems within the existing DoD acquisition structure.

Midshipman Research Course Projects

Human Interface Device Design for Simulating a Manual Transmission

Researcher: Midshipman 2/C Steven A. Ekdahl, USN
Adviser: Assistant Professor David J. Stahl, Jr.

This successfully completed project required software and hardware design and implementation of, (1) human input mechanisms to simulate a clutch pedal and engine transmission state, (2) a Microsoft Windows application to display this input graphically, and (3) an I/O device to read the input mechanisms and drive the display. Specifically, the USB standard

is used as the interface between a physical input mechanism and a simulated application. The mechanical position of a clutch pedal is modeled using a potentiometer, and the engaged or disengaged state of a transmission gear is modeled using a switch. Pedal position and transmission state is visualized in real time, on-screen. The results of this research provide a foundation for anticipated follow-on development of a more sophisticated transmission model, including engine response and force-feedback.

Simplifying Large Formulas in Parallel on a Beowulf Architecture

Researcher: Midshipman 1/C Anthony J. Vespa, USN
Adviser: Assistant Professor Christopher W. Brown

Many algorithms for symbolic computing with semi-algebraic sets produce solutions in the form of extremely large boolean combinations of polynomial equalities and inequalities – formulas consisting of thousands of (in)equalities. While such a formula may technically be the solution to a problem, it's not a very useful solution. Thus, simplification of these formulas is an important problem. Mr. Vespa's work was to take an existing program for simplifying large formulas of this type and parallelize it. He based his parallel implementation on the MPI library, and tested it on the Academy's Beowulf cluster. Mr. Vespa's work was presented as a poster at the East Coast Computer Algebra Day at Clemson University.

Trident Scholar Projects

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

Researcher: Midshipman 1/C Bryan M. Hudock, USN
Advisers: Associate Professor Bradley E. Bishop (Weapons and Systems Engineering Department)
and Assistant Professor Frederick L. Crabbe, IV

The September 11th bombing of the World Trade Centers in New York illustrated the many problems associated with rescuing the survivors of a collapsed building. The fact that survival probability drops dramatically after two days, combined with the massive amount of debris that needs to be explored, makes the urban search-and-rescue mission extremely daunting. In addition, the environment within a pile of debris is very unstable and often too dangerous for entry by humans. The solution to such a complicated problem lies in robots capable of quickly exploring a collapsed building and pinpointing the location of any survivors.

The focus of this project was designing and building an urban search-and-rescue robot. The primary goal was to develop a physical structure that would be unique and versatile enough to traverse different terrain challenges. A design's effectiveness was judged on its ability to overcome the pre-selected terrain types. The secondary goal was to simplify operator input by establishing a 'fly-by-wire' style controller, wherein user inputs are mapped to motor motion commands that are developed using a physics simulator. Initially, a simulation model of the robot needed to be created with responses that closely correlated to the responses of the actual prototype. Using the simulation, various methods, including genetic algorithms, were used to develop locomotive methods, or 'gaits,' for various types of motion, i.e., lines and curves. The movements were then translated to the physical prototype and their effectiveness (the ability to move as predicted) analyzed. The end result was a robot with a versatile mobility controlled using simple operator inputs.

Efficient Academic Scheduling at the U.S. Naval Academy (Trident Report # 317)

Researcher: Midshipman 1/C David L. Zane, USN
Advisers: Assistant Professor William N. Traves (Mathematics Department)
and Assistant Professor Christopher W. Brown

This project examined academic scheduling problems at the U.S. Naval Academy. The focus was on devising methods to construct good final exam schedules and improve existing course schedules by facilitating course changes.

The final exam scheduling problem is an example of an NP-hard problem. These difficult problems do not admit efficient deterministic solutions. Several heuristic methods to treat these problems were considered. An approach using genetic algorithms showed particular promise. Genetic algorithms involve mating "parent" schedules to form favorable

"offspring" schedules and then subjecting these new schedules to local mutation. A computer program implementing these ideas was created and tested.

Section changes at the Naval Academy had been done on an ad-hoc basis, but this project determined that it could be streamlined and improved by using a centralized barter system. The barter technique accepts input listing desired section changes and identifies multi-student section changes to accommodate their desires. A prototype computer program that uses network flow algorithms to find such section changes was devised. In addition, a method incorporating integer programming techniques was examined and tested.

Publications

Journal (Refereed) Manuscripts

HOGAN, Thomas R., Commander, (USN), HARRISON, Patrick R., Professor and SCHULZE, Kay G., Professor, "Developing and Maintaining an Effective Assessment Program" SIGCSE Bulletin, Vol. 34, No. 4, December 2002, pp. 52-56.

The increased emphasis on assessment by regional accrediting bodies and the Computing Accreditation Commission of ABET has caused institutions of higher education and Computer Science departments to seriously consider the tools and techniques they are using to evaluate their program's effectiveness. With the current shortage of computer science professors at many schools, the time available to develop and maintain an effective assessment program has been greatly reduced. Successful assessment programs require the development of a variety of carefully chosen and properly timed assessment instruments to be effective and yet avoid overburdening faculty. Successful assessment also requires a process model that carefully builds faculty support for the assessment process.

Conference Proceedings

CRABBE, Frederick L., IV, Assistant Professor, "Compromise Candidates in Positive Goal Scenarios," *Proceedings of the 7th International Conference on Simulation of Adaptive Behavior (SAB)*, Edinburgh, Scotland, August 2002, pp. 105-107.

Devising a solution to the action selection problem rests on a definition of what actions are preferable over others. Among many properties suggested for action selection mechanisms, one prominent one is the ability to select compromise actions, i.e. actions that are not the best to satisfy any active goal in isolation, but rather compromise between the multiple goals. This paper performs a mathematical and experimental analysis of compromise behavior in an attempt to determine exactly how much compromise behavior aids an animat. The paper concludes that the ability to select compromise actions does provide some additional welfare to the animat, but less than previously postulated.

CRABBE, Frederick L., IV, Assistant Professor, "On Learning to Select Actions in Multiple Goal Scenarios," *Proceedings of the International Conference on Computational Intelligence for Modelling Control and Automation (CIMCA)*, Vienna, Austria, February 2003, pp. 247-257.

This paper addresses issues concerning using reinforcement learning for mobile robotic agents to learn to achieve multiple goals. It examines the approach of separating the system into multiple learning systems, one for each goal, and having the agent act upon the strongest goal at any one time. It will prove that an agent that behaves in this manner will not behave optimally according to Utility Theory. The paper then examines solving the problem with a single learning system using three different functions approximators: linear, bi-linear, and neural network. It concludes that the linear function is not expressive enough to characterize the problem, but that a bi-linear system is expressive enough and more efficient than a neural network. Finally, the paper presents empirical results comparing a bi-linear Q-learner with a linear Q-learner and a neural network based Q-learner on a multiple goal task. The experiments show that bi-linear functions do indeed work better than linear functions; work as well as neural networks; and converge significantly faster than neural networks.

DATKO, Joshua B., Ensign, (USN), McMAHON, Margaret M., Assistant Professor and NEEDHAM, Donald M., Associate Professor, "Supporting Secure, Ad Hoc Joins for Tactical Targeting Network Technology," *Proceedings of the 3rd International Networking Conference*, Plymouth, UK, July 2002, pp. 123-130.

The Defense Advanced Research Project Agency's Tactical Targeting Network Technology (TTNT) initiative focuses on improving distributed command and control in tactical military environments. A goal of TTNT is to provide a low-latency, high bandwidth, and dynamically re-configurable network infrastructure that can disclose the full potential of the network to the warfighter. We examine existing joining algorithms to determine their compatibilities and abilities to meet the networking needs of TTNT from a security perspective. We identify and outline protocols needed to support such a TTNT Network, and present an algorithm that provides a foundation for secure, ad hoc joining within a distributed, mobile, wireless network.

McMAHON, Margaret M., Assistant Professor, DATKO, Joshua B., Ensign, (USN) and NEEDHAM, Donald M., Associate Professor, "An Authentication Scheme for a Jini-based Ad Hoc Network," *Proceedings of the 15th International Conference on Parallel and Distributed Computing Systems*, Lexington, KY, September 2002, pp. 462-467.

Ad hoc networks provide a low-latency, high bandwidth, and dynamically reconfigurable network infrastructure that can disclose the full potential of the network to the user. Use of Jini technology in an ad hoc environment allows the user to enter a network and become a user of services without *apriori* knowledge of the existence of the network or its services. However, Jini lacks security provisions for entry into the network. This paper presents an algorithm that provides a foundation for secure, ad hoc joining of a distributed, mobile, wireless network based on Jini architecture. We also present the description of a Java-based implementation of certification authority hierarchy to support the authentication process.

McMAHON, Margaret M., Assistant Professor, "Development of a String Metric for Dynamic Authentication," *Proceedings of the 15th International Conference on Parallel and Distributed Computing Systems,* Lexington, KY, September 2002, pp. 455-461.

Networks are now essential for everyday communication and commerce. Passwords provide a static means of authentication. The passwords that users choose, use, and protect, remain one of the most vulnerable aspects of using a network. A compromised password permits a masquerader to enjoy all the privileges of the account owner. Misuse may not be detectable in real-time; it may only be apparent after damage to files, systems, commercial property, or privacy has occurred. By using a dynamic form of authentication, intruders may be uncovered while attempting to gain access.

User behavior can be characterized by the commands used, the order of those commands and the timing between them. Each user's behavior is captured in an expanded, probabilistic automaton. Dynamic authentication compares current input to the historical information for all authorized users of the system using Bayes' Theorem. The string metric is one of several possible discriminators based on the information available. An intruder performing different commands in a different order from the authorized user will not match the behavior stored in that user's automaton, and that user will fail the authentication process.

This article discusses the modeling of users, and the definition of one metric for dynamic authentication, the string metric. The sequence of experiments performed to define and refine the string metric is presented. The metric progressed from being applied to five, then twelve users, and most recently to twenty users. Results show that the average identification of users increases slightly as the number of users increases.

McMAHON, Margaret M., Assistant Professor, and Buscher, David, "A Hub-and-Spoke Architecture for Netcentric Operations (Urban Security)," *Proceedings of the Government Microcircuit Applications & Critical Technology Conference (GOMAC*), Tampa, FL. (CD-ROM)

The dispersion and variety of forces involved in an urban security environment dictate the dissimilar and diverse command and control (C^2) environment of asymmetric warfare. This environment is demanding on both communications and sensor systems. Communication and data sharing are required between the several different entities tasked with ensuring urban security: local, state, federal, and military entities.

Communication is required between the forces; between stationary and mobile units of the forces, including teams on the ground; and with supporting aircraft. Current communication systems are inadequate to address these issues; they have significant interoperability problems. Given the state of communication systems, the flexibility of highly mobile responses will be limited, hindering the success of urban security operations.

These efforts require flexible and reliable communications. Current Line-of-Sight (LOS) communications lack both the distance and the capacity to transfer information required by end-users. Current LOS communications need to be augmented by wide area communications to provide Beyond-Line-of-Sight (BLOS) capability. Coordination is necessary among the different participants, and the different units within those entities. This coordination is essential for all participants to understand the urban environment and to support coordinated responses to situations as they arise. The interface between local and global communications must be seamless to the end-users and information sources.

NEEDHAM, Donald M., Associate Professor, Demurjian, Steven, Price, Margaret, Rando, Thomas and Daggett, Thomas, "Analyzing the Reusability of XML Components," *Proceedings of the 6th International Business Information Systems Conference (BIS2003)*, Colorado Springs, CO, 3-6 June 2003, pp. 258-262.

Developing reusable components in an objected-oriented system typically centers on identifying and evaluating couplings between data abstractions such the data members and member functions of Java or C++ classes, and then, if possible, refactoring the design to remove coupling that negatively impacts reuse. Likewise, designing reusable XML components requires an understanding of the role of the XML Schema Language in defining the structure of documents, as well as the dependencies introduced by various design approaches. This paper examines the issue of reusability regarding XML documents, and focuses on schema design decisions that impact reuse with a focus on reusability within the shipbuilding domain. We explore three different schema design techniques, with a focus on reusability and extensibility. We present empirical results based upon ongoing XML schema development at the Electric Boat, Inc., and discuss schema design guidelines for developing reusable XML components.

YOUNG, Paul E., Captain, (USN), Chaki, Nabendu, Luqi, and Berzins, Valdis, "Evaluation of Middleware Architectures in Achieving System Interoperability," *Proceedings of the Rapid Systems Prototyping 2003 Conference*, San Diego, CA, June 2003, pp. 108-116.

The current state-of-the-art for integration of heterogeneous systems involves manually resolving differences in data modeling and mapping for each interface between systems, in an inherently customized manner. The first step in advancing the state-of-the-art is to develop a general model of the interoperation among systems. Keeping this as the broad objective, in this paper we have worked on classification of modeling differences among autonomously developed, heterogeneous systems as differences in what is being modeled (view) and differences in how the modeled information is represented (representation). Further to this, a set of criteria was selected for conducting an evaluation of existing interoperability approaches in order to compare their success in resolving such heterogeneities. These criteria were used to evaluate six of the leading approaches for achieving interoperability among independently developed systems. The limitations of these approaches against the criteria provided the motivation for subsequent development of a general model of the interoperation among systems, the Federation Interoperability Object Model (FIOM) used in the Object-Oriented Method for Interoperability (OOMI), to address these shortcomings.

Presentations at Professional Meetings and Conferences

BROWN, Christopher W., Assistant Professor, "Implementing Q.E. by CAD to be Complete, Correct, Fast and Good," Conference on the Applications of Computer Algebra, Volos, Greece, 25 June 25 2002.

CRABBE, Frederick L., IV, Assistant Professor, "Compromise Candidates in Positive Goal Scenarios," 7th International Conference on Simulation of Adaptive Behavior (SAB), Edinburgh, Scotland, 7 August 2002.

CRABBE, Frederick L., IV, Assistant Professor, "On Learning to Select Actions in Multiple Goal Scenarios," International

Conference on Computational Intelligence for Modeling Control and Automation (CIMCA), Vienna, Austria, 13 February 2003.

LENNERTON, Mark J., Major, (USMC), "Exploring a Chromakeyed Augmented Virtual Environment for Viability as an Embedded Traingin System for Military Helicopters," MOVES Open House, Monterey, CA, August 21, 2002.

McMAHON, Margaret M., Assistant Professor, "Supporting Secure, Ad Hoc Joins for Tactical Targeting Network Technology," 3rd International Networking Conference, Plymouth, UK, 18 July 2002.

McMAHON, Margaret M., Assistant Professor, "Use Cases, Local/Global Networks," for NAVAIR Sponsor, Laurel, MD, 12 September 2002.

McMAHON, Margaret M., Assistant Professor, "Use Case, Local/Global Networks Briefing, Roundtable Discussion," Naval Surface Warfare Center -Dahlgren Division, Dahlgren, VA, 7 November 2002. (Invited talk)

NEEDHAM, Donald M., Associate Professor, "JTO Review of HEL M&S Program," Joint Technology Office, Albuquerque, NM, 29 January 2003.

NEEDHAM, Donald M., Associate Professor, "Applying Software Engineering Techniques to the Computer Science Assessment Process," Best Assessment Processes V Symposium, Terra-Haute, IN, 25 April 2003.

NEEDHAM, Donald M., Associate Professor, "Analyzing the Reusability of XML Components," 6th International Business Information Systems Conference (BIS2003), Colorado Springs, CO, 5 June 2003.

YOUNG, Paul E., Captain, (USN), "Evaluation of Middleware Architectures in Achieving System Interoperability," Rapid Systems Prototyping 2003 Conference, San Diego, CA, 9-11 June 2003.