Computer Science Department

Professor Patrick R. Harrison
Chair

During the 2001-2002 academic year, the Computer Science Department faculty did significant research in the areas of software engineering, robotics, security, computer algebra, and intelligent tutoring and advanced distributed computing. This included the publication of four papers, two book chapters and four presentations. A number of independent research projects were conducted. Midshipmen also participated in a number of summer internships. Two Trident projects were completed, including one on robotics and the other on netcentric warfare. The Computer Science faculty continues to attract grant money and research opportunities from both government and commercial sources. This year the department developed a 17-node Beowulf cluster to support research in parallel processing and a new advanced Information Assurance laboratory 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)

Cylindrical Algebraic Decomposition (CAD) is a powerful data structure for explicitly representing *Semi-Algebraic Sets* which, roughly speaking, are any geometric objects defined by polynomials. Many problems in mathematics, science, and engineering may be phrased as questions about semi-algebraic sets, and CAD is a powerful tool for answering these questions. The ultimate goal of this project was to improve upon the current state of the art in algorithms for using and constructing CAD's so as to increase the range of problems that can be addressed in practice with these methods. This project looked at two distinct problems. First, it addressed some technical issues in CAD construction algorithms on which research papers have been vague and which actual programs have hitherto ignored. This work resulted in a technical report and a version of the program QEPCAD that treats these technical issues correctly. The second investigated the use of validated numerical techniques to greatly improve CAD construction for the important special cases of 2 and 3 dimensions.

Social Learning and Compromise Behavior in Robots and Situated Agents Performing a Construction Task

Researcher: Assistant Professor Frederick L. Crabbe, IV
Sponsors: Office of Naval Research (ONR) and Naval Academy Research Council (NARC)

This project investigated compromise behavior in mobile robots. Compromise behavior occurs when a robot has multiple conflicting goals for which the optimal global solution is not the optimal solution for any sub-goal. This work showed that in some cases previously believed to be situations calling for compromise behavior, such behavior does not provide much benefit for the robot. This work will continue to examine this question to determine when and how much compromise behavior is beneficial to a robot.

Imitation Learning of Goal Sequences in Mobil 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 performed 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. This project focused 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, Inc.

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 work is proprietary.

Development of Bayesian-Based Mechanisms for Real-Time Network Security Systems

Researcher: Assistant Professor Margaret M. McMahon
Sponsors: Office of Naval Research (ONR) and Naval Academy Research Council (NARC)

Networks are increasingly important in this information age. At many points in network routing, passwords can be captured and an account misused without triggering any alarm. Once admitted, an intruder has all the privileges the account owner enjoys. If there is detection, it is typically after damage to files, systems, or commercial property rights have occurred. Intruders should be uncovered when attempting to gain access, however, authenticating devices at every access point is prohibitively expensive, and prior exchange of passwords may be impractical. This research explored the elements of a real-time dynamic authentication system based on users' behavioral patterns.

These elements protect the system, administer it, contain decision mechanisms and respond to changes in user behavior. The commands used, their order, and the timing between them characterize behavior. Our approach was based on an experimental authentication tool developed at the University of Connecticut. This dynamic approach to user authentication provides intrusion detection, and potential identification. Differences between current input and models stored in the system may indicate a masquerader, an intruder, or a change in a user's behavior or intent.

Reusability Analysis Framework for Shipbuilding Components Modeled in EXPRESS, XML, and Java

Researchers: Associate Professor Donald M. Needham
and Steven A. Demurjian, Sr., Ph.D.
(University of Connecticut, Department of Computer Science and Engineering)
Sponsor: The Electric Boat Corporation, Groton, Connecticut

In order to support interoperability in the Integrated Shipbuilding Environment (ISE), under research investigation at Electric Boat, it is necessary to define shipbuilding components at different levels of abstraction, which support application-to-application interoperability at design and implementation levels. Possible candidates for such abstractions include EXPRESS, XML, and Java, which cover a range of conceptual to development languages. A critical factor in this work is the creation of reusable shipbuilding components and interfaces, at both design and development levels. Current research in reusable compo-

nents concentrates primarily on the consumer (reuser) perspective instead of the producer perspective. Typically, studies focus on measuring the reuse that a software project has achieved (or how much effort has been saved by reuse) instead of on measuring the degree that an application is reusable for other similar systems that will be built in the future. For instance, in 1996 Lim compared seventeen reuse economic models that measure savings from reuse and return on investment, while in 1997 Poul reviewed nine similar models. While many of these models show a great deal of commonality, there is still less attention given to analyzing reusability during system design and development in order to produce reusable products. However, research efforts have begun to mature as evidenced by the creation of reusable software research groups at universities led by Wvu and Osu.

Andes: An Active Learning, Intelligent Tutoring System for Newtonian Physics

Researchers: Professor Kay G. Schulze,
Professor Robert N. Shelby, Professor Donald J. Treacy,
and Professor Mary C. Wintersgill (USNA Physics Department)
and Dr. Kurt VanLehn (University of Pittsburgh)
Sponsor: Cognitive Sciences, Office of Naval Research

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 to be used as a "homework helper" for students taking Physics. This year the project concentrated on modeling electricity and magnetism problems and improving the help system.

Research Course Projects

Embedded Systems with Java and QNX

Researchers: Midshipman 1/C Michael Simpson, USN
and Midshipman 1/C Brian Whitten, USN
Adviser: Associate Professor Donald M. Needham

This research course focused on the design, development and implementation of a reusable, embedded, multi-threaded control system for the Naval Academy's 2002 Autonomous Underwater Vehicle (AUV) competition entry. The midshipmen worked in conjunction with midshipmen in the Systems Engineering, Naval Architecture, Ocean Engineering, and Mechanical Engineering departments to design, build, and enter an AUV into the Association for Unmanned Vehicle Systems International's (AUVSI) annual competition. In previous years, interdisciplinary teams of midshipmen entered the AUVSI competition and physically constructed the AUV during the spring semester, with little reuse of the previous year's control systems, due primarily to the intentionally changing annual competition rules. In previous years teams typically spent the balance of the semester analyzing and constructing circuits for the sonar system, navigation system, and measuring power requirements. This research project focused primarily on the development of a Java-based, multi-threaded software system to provide a reusable platform to test AUV hardware components during system construction and to provide the control logic to allow autonomous command of the AUV during the actual competition.

Trident Scholar Projects

Supporting Secure, *AdHoc* Joins for Tactical Networks

Researcher: Midshipman 1/C Joshua B. Datko, USN
Advisers: Assistant Professor Margaret M. McMahon
and Associate Professor Donald M. Needham

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 war-fighter. This project examined Jini and Bluetooth joining algorithms to determine their compatibilities and abilities to meet the networking needs of TTNT from a security perspective. It identified and outlined protocols needed to support such a TTNT Network, and presented an algorithm that provides a foundation for secure, ad hoc joining within a distributed, mobile, wireless network.

Acquisition of 3-D Map Structures for Mobile Robots

Researcher: Midshipman 1/C Edward H.L. Fong, USN
Adviser: Assistant Professor Frederick L. Crabbe, IV

For an autonomous mobile robot to move around intelligently in its surroundings, it must possess a map of the environment which it can use to determine where it is, where it wants to go, and the best way to get there. The ability to successfully navigate in its surroundings allows the robot to perform more complicated tasks with greater autonomy. When a mobile robot is introduced into an unfamiliar environment, it does not have that map available and therefore must generate one itself. Methods currently exist to perform such a task in an environment where the robot moves about a single plane. However, this limitation restricts the robot's movement to a flat and smooth surface (typically an indoor setting). This project built upon current map building techniques to enable a ground-based mobile robot to navigate robustly in an unfamiliar, more three-dimensional (outdoor) environment. A new map structure was developed to store three-dimensional information in a compressed form. It represented the robot's environment as a two-dimensional surface existing in three-dimensional space. This map structure was implemented on an all-terrain outdoor robot for use in urban environments. The map structure was tested both by comparing generated maps to the environment on which they were based, and by testing the robots ability to navigate with them. The map structure was shown to accurately model the robot's environment and enable the robot to navigate in it while requiring few computational resources.

Publications

Journal (Refereed) Manuscripts

BROWN, C.W. Assistant Professor, "Improved Projection for Cylindrical Algebraic Decomposition," *Journal of Symbolic Computation*, 32(5): pp. 447-465, November 2001.

> McCallum's projection operator for Cylindrical Algebraic Decomposition (CAD) represented a huge step forward for the practical utility of the CAD algorithm. This paper presented a simple theorem showing that the mathematics in McCallum's paper actually point to a better projection operator than he proposes – a *reduced* McCallum projection. The reduced projection has the potential to not simply speed up CAD computation for problems that are currently solvable in practice, but actually increase the scope of problems that can realistically be attacked via CADs. Additionally, the same methods were used to show that McCallum's projection can be reduced will further when CAD is applied to certain types of commonly occurring quantifier elimination problems.

Book Chapters

CRABBE, F. L. IV, Assistant Professor, Martin, P., Adams, S., Baatz, E., and Yankelovich, N., "SpeechActs: A Spoken Language Framework," *Sun Microsystems Laboratories: The First Ten Years 1991-2001*, (Treichel and Holzer, eds.), pp. 33-40. (2001)

SpeechActs is a prototype testbed for developing spoken natural language applications. It enables software developers without special expertise in speech or natural language processing to create effective conversational speech applications, that is, applications with which the user can speak naturally, as if they were conversing with a personal assistant.

VanLehn, K., Lynch, C., Taylor, L., Weinstein, A., SHELBY, Robert N., Professor, SCHULZE, Kay G., Professor, TREACY Donald J., Professor, and WINTERSGILL, Mary C., Professor, "Minimally Invasive Tutoring of Complex Physics Problem Solving," *Intelligent Tutoring Systems*, (Cerri, Gouarderes, Paraguacu, eds.), pp. 367-376. (2002)

Solving complex physics problems requires some kind of knowledge for selecting appropriate applications of physics principles. This knowledge is tacit, in that it is not explicitly taught in textbooks, existing tutoring systems or anywhere else. Experts seem to have acquired it via implicit learning and may not be aware of it. Andes is a coach for physics problem solving that has had good evaluations, but still does not teach complex problem solving as well as we would like. The conventional ITS approach to increasing its effectiveness requires teaching the tacit knowledge explicitly, and yet this would cause Andes to be more invasive. In particular, the textbooks and instructors would have to make space in an already packed curriculum for teaching the tacit knowledge. This paper discussed our attempts to teach the tacit knowledge without making Andes more invasive.

Conference Proceedings

CRABBE, F.L., IV, Assistant Professor, "Multiple Goal Q-Learning: Issues and Functions," *Proceedings of the International Conference on Computational Intelligence for Modeling, Control and Automation*, September 2001, pp 178-185.

This paper addressed the concerns of agents using reinforcement learning to learn to achieve multiple goals. It proved that an algorithm based on acting upon the maximal goal at any one time will not always produce the Maximal Expected Utility for the agent. The paper then examined the type of function approximator necessary for the agent and concluded that bi-linear function was the best compromise between expressive power and speed of learning.

McMAHON, M.M., Assistant Professor, Ammar, R.A., and Sholl, H.A., "Proposed Structure of a Network Security System Using Dynamic Authentication,"*14th International Conference on Parallel and Distributed Computing Systems*, August 2001, pp. 183-189.

Networks are increasingly important for communicating and commerce in everyday life. Passwords are vulnerable at many points in network routing, and allow a masquerading intruder to misuse an account without triggering any alarm. Once admitted, an intruder has all the privileges enjoyed by the account owner. Even if misuse is detected, it is typically after damage to files, systems, commercial property, or privacy has occurred. Intruders should be uncovered while attempting to gain access. Authenticating devices at every access point is logistically impractical; prior exchange of passwords may be unfeasible.

This research explored the elements of a real-time dynamic authentication system based on users' behavioral patterns. User behavior is characterized by the commands used, their order, and the timing between them. This dynamic approach to user authentication provides intrusion detection, and potential identification using Bayes'

theorem. Differences between current input and models stored in the system may indicate a masquerader, an intruder, or a change in an authorized user's intent.

Our work focused on refining and defining metrics of an approach for dynamic user authentication. We investigated the influence of sample size and state space on our ability to recognize the presence of individuals using a computer system.

SCHULZE, Kay G., Professor, SHELBY, Robert N., Professor, TREACY, Donald J., Professor, WINTERSGILL, Mary C., Professor, VanLehn, K., and Weinstein, A., "An Assessment of the Andes Tutor," *Proceedings of the Physics Education Research Conference*, Rochester, NY, July 2001, pp. 119-122.

Andes is an intelligent problem-solving tutor for classical physics. It was used in the fall semesters of 1999 and 2000 by a group of approximately 150 students. An assessment of its effectiveness was made using: 1) comparative results on a free-response test taken by the Andes group and a control group, 2) portfolios of the students' work, and 3) student opinion surveys. The results of the assessment highlight some strengths and weaknesses of Andes.

Presentations

CRABBE, F. L., IV, Assistant Professor, "Multiple Goal Q-Learning: Issues and Functions," Meeting of the International Conference on Computational Intelligence for Modeling Control and Automation," (CIMCA), Las Vegas, NV, July 2001.

McMAHON, M. M., Assistant Professor, "Proposed Structure of a Network Security System Using Dynamic Authentication," 14th International Conference on Parallel and Distributed Computing Systems, Dallas, TX, August 2001.

SCHULZE, K. G., Professor, TREACY, D., Professor, SHELBY, R., Professor, and WINTERSGILL, M., Professor, "Andes: A Tutoring System for Classical Physics," 6th National Physics Education Research Conference, Rochester, NY, July 2001.

VELAZQUEZ, L., Major, (USMC) and HARRISON, P. R., Professor, "Student Enterprise Solutions in the Computer Science Curriculum," ACM SIGCSE 2002, Cincinnati, OH, March 2002.