The School of Information and Computer Science

Established in 1963, the School of Information and Computer Science is rapidly improving its position as one of the better computer science departments in the country. A 1982 survey by the Conference Board of Associated Research Councils ranked the School "most improved" among the fifty-seven Ph.D-granting computer science departments included in the study. Although the survey did not rank the departments overall, an average of the four most important rating parameters would place the School fourteenth.

The School of ICS has two missions - education and research - and strives for excellence in both.

Education
The School awards bachelor's, master's, and doctoral degrees in information and computer science. The B.S. program offers students a well-rounded education in information and computer science; students take a standard sequence of courses until the senior year when they choose areas of specialization. The M.S. degree offers more advanced training. Fifty credit hours are required for the M.S. degree, including required courses in six subjects. The Ph.D. program is designed to prepare students for academic and research careers. No set number of hours is required for the degree. The program emphasizes a broad understanding of information and computer science coupled with intensive study in the students' area of specialization, culminating in a doctoral dissertation. With approximately 300 students (500 undergraduates, 160 masters, and 70 doctoral), the School of ICS is the seventh-largest academic unit at Georgia Tech overall but has the second-largest graduate enrollment.

The educational programs of the School are supported by a wide variety of computer equipment, both introductory and advanced. For example, the School's IBM Computer-Supported Instruction Laboratory, which includes ten classrooms, is connected to an IBM 4381 through three IBM Series 1 systems. The Artificial Intelligence Instructional Laboratory contains more than a dozen Xerox 1108 Dandelion workstations. Another classroom-laboratory contains ten AT&T 3B2 systems. Special equipment for instruction in computer graphics includes a Tektronix 4116 system, twelve Tektronix 4137 graphics terminals, and four Xerox 6114 printers. Some ICS classes use the facilities of the campus computing center, which operates four CDC CYBER 180 systems (models B5, B50, B55, and B56), an IBM 3031, two IBM 4340s, two IBM 3930s, fifteen AT&T 3B2s, and a Xerox 9100 laser printer.

Research
ICS faculty members perform research in areas that span the field of information and computer science. Faculty in many of these areas are nationally and internationally recognized experts. Many fields contribute to the research environment in the School of ICS. Most important is funding, which is provided largely by government agencies although private industry, through grants of equipment and funds, makes a notable contribution as well.

Another factor is fast communication of research results. For this purpose, the School sponsors an active colloquium series as well as specialized seminars in software engineering, theoretical computer science, artificial intelligence, and computer networking. Key ingredients in any research program are the quality and quantity of computing power available. The School is fortunate to have a rich collection of computer systems. The School's DEC VAX 11/780, a Supermicro Graphics System, a CAD System, and a Supercomputer, all use Xerox 9140 laser printers used for high-quality printing of technical papers and research proposals. Many of the School's computing systems are linked by the NetWare local network, which in turn connects to a campus-wide network. The latter network provides dial-in access to any machine on it.
What's New in ICS

The 1985-86 academic year saw many important developments for the School, including final approval for a new building to house ICS, accreditation for the undergraduate program, and the establishment of the Software Engineering Research Center.

Georgia Tech observes Centennial

Georgia Tech celebrated its Centennial in 1985. The festivities included "Showcase 85," an open house held on October 11. ICS was one of many schools and departments participating; visitors to the School were given tours demonstrating research in computer networks, software engineering, artificial intelligence, and computer graphics.

Final plans approved for new computer science building

Final plans have been approved for a new building to house the School of ICS. The School will occupy two floors (a total of 68,000 square feet) of the five-story building; the other floors will provide space for the computing sciences accreditation program, lecture halls and classrooms as well as some facilities of the School of Chemistry. The new building will be adjacent to the new Microelectronics Research Center building, which is currently under construction.

The two ICS floors will include the following:
- Fifty-nine faculty offices and 158 graduate student carrels
- Two classroom laboratories, each with thirty-five student workstations, and one classroom-laboratory with sixty workstations
- A hardware laboratory with twenty benches, each accommodating two students
- An instructional networking laboratory
- A machine room
- Six research project laboratories
- Four seminar-conference rooms and two common rooms
- A computer science and information library

The state of Georgia has already appropriated funds for the new building. Construction contracts are expected to be awarded in the fall of 1986; the building should be completed twenty months later.

Undergraduate program receives accreditation

The ICS undergraduate degree program was accredited in 1986 by the Computing Sciences Accreditation Board, Inc. (CSAB). CSAB was established in 1954 by the Association for Computing Machinery and the IEEE Computer Society. The ICS undergraduate program was among the first group of twenty-two programs to be accredited.

Software Engineering Research Center is created

The Software Engineering Research Center (SERC) was established in the fall of 1985 as the newest of Georgia Tech's multidisciplinary research centers. SERC is dedicated to research, development, and technology transition; its domain includes all technologies that aid in the efficient production of low-cost, high-quality software. Although SERC is a separate entity from ICS, it maintains close ties with the School. ICS Professor Richard DeMillo is the director of SERC, and several ICS faculty members are on the SERC staff.

Artificial intelligence research group introduces AI to Tech campus

During the 1985-86 academic year, the School's artificial intelligence research group, directed by Professors Richard Cullingford and Janet Kokoliner, sponsored a series of campuswide events designed to introduce AI to the Tech community. A monthly AI colloquium series brought distinguished researchers to Tech, including Michael Genesinder, Geoffrey Hinton, Elaine Kant, David Waltz, Michael Dexter, Mark Fox, Elaine Rich, Andrew Ortony, and Brian Ross. Other events included an all-day AI Satellite Symposium on Expert Systems and an intensive, one-week AI course for Tech faculty and staff, conducted in the new AI Instructional Laboratory. The events proved to be a success, and the colloquium series will continue during the 1986-87 academic year.

New faculty joins ICS

The School was fortunate to hire four new faculty members in 1986:
- William F. Apelgren, Associate Professor. A native of Australia, Professor Apelgren received the Ph.D. from the University of British Columbia in 1979. From 1979 to 1984, he was a faculty member at the University of California at San Diego. His interests include software engineering, computer architecture, language design, and formal methods.
- Patrick C. Fischer, Assistant Professor. After receiving the Ph.D. from Georgia Tech in 1981, Professor Fischer taught at Indiana University. His interests include computer science aspects of distributed and parallel systems and software engineering.
- Shichao (Peter) Fan, Assistant Professor. After receiving the Ph.D. from North Carolina State University in 1984, he joined the School in 1986. His research interests include parallel processing and communication.
- Aaron R. Gersho, Assistant Professor. After receiving the Ph.D. from Columbia University, he joined the School in 1986. His research interests include artificial intelligence and computer science.

What's New in ICS
Academic Faculty

Mustafah Amyot. Assistant Professor. Ph.D., University of Waterloo. 1983. Distributed operating systems and protocols, large-scale information delivery systems, queuing theory.


Research Faculty


Staff

Technical


Administrative and Secretarial

Edmund F. Rumiano. Assistant to the Director.

Debra B. Kelley. Staff Assistant.

Visitors


The Georgia Institute of Technology, founded in 1889, offers educational programs in science, engineering, management, and architecture. Georgia Tech is a unit of the University System of Georgia, which operates thirty-one colleges and universities. Tech currently enrolls more than eleven thousand students, representing every state and eighty-nine countries. The quality of the student body is high; Tech enrolls the highest percentage of freshmen National Merit Scholars and National Achievement Scholars among publicly supported U.S. colleges.

The athletic programs at Georgia Tech are nationally famous, as are the "Ramblin' Wreck" parade and other school traditions. The football, basketball, baseball, and golf teams all finished the 1985-86 season ranked among the top twenty in the nation. The football team was particularly successful; in addition to finishing sixth in the nation, the Yellow Jackets won their fourth consecutive ACC rookie-of-theyear award and rallied the jocund Sea Island crowd for a victory over North Carolina. Demand for basketball tickets was so inordinate that $24.4 million is being spent to increase the seating capacity of Alexander Memorial Coliseum by 2,104. The campus of Georgia Tech covers three hundred acres near downtown Atlanta. The School of Information and Computer Science occupies a portion of the Rich Building, a modern structure near the center of campus that also houses the Office of Computing Services.

Located near the Rich Building, the Price Gilbert Memorial Library contains over 1.9 million volumes and 2.4 million microforms and receives 28,000 periodicals. The library's catalog is being placed on microfilm with copies available at many locations in the library and at other locations on campus. Other campus facilities include a modern student center and a recently expanded bookstore. The Student Athletic Complex contains eight racquetball/handball courts, two squash courts, a twenty-five-meter swimming pool, and facilities for basketball, volleyball, badminton, tennis, weight training, and table tennis.

Georgia Tech conducts an extensive research program. For the 1985-86 fiscal year, research expenditures exceeded $100 million, a 15 percent increase over the previous year. Tech ranks first among public universities in engineering research and development expenditures. In conjunction with Georgia Tech's Centennial, the university began a five-year, $100 million fund-raising drive in 1983. Just three years later, the total raised exceeded $80 million, making the campaign—on a per-student basis—the most successful fund-raising effort ever conducted by a U.S. public university. The campus goal has since been increased to $145 million.

Atlanta

Atlanta, founded in 1837 and almost completely rebuilt after its destruction in 1964 by General Sherman, has become the leading city in the Southeast—a center for industry, finance, and transportation. Atlanta's metropolitan area, which spreads over eighteen counties and includes 2.5 million people, is the thirteenth largest in the country and the fifth fastest growing. The city's location makes it a crossroads for all forms of transportation—railroads, highways (i.e., interstate highways), freeways, and airlines. Atlanta's Hartfield International Airport is the busiest in the world. Because of its location and facilities, Atlanta is the third most active convention city in the nation. At an altitude of 1,050 feet above sea level, Atlanta's elevation is greater than that of any other major American city except Denver. Its moderate climate encourages year-round outdoor activities. Residential areas are among the most attractive in the United States, and houses are reasonably priced.

Transportation in the city is excellent, thanks to an extensive set of bus routes and a new rapid transit system. The massive "Freeway the Freeways" program, which began in 1981 and is scheduled for completion by 1988, will give Atlanta one of the best freeway systems in the country. This $4.5 billion program is the largest highway project in the history of Georgia. Numerous hotel and convention facilities are available for business and leisure travelers. The Atlanta Symphony Orchestra, the Atlanta Opera, the Atlanta Ballet, and the Atlanta Repertory Theatre are among the finest in the nation. The city is also home to the largest number of restaurants in the United States.

The area includes Lenox Square, a huge mall containing two hundred stores and restaurants. Good restaurants of all kinds abound in Atlanta, from the inexpensive Southern cooking of Mary Mac's to the haute cuisine of Nelle's Roof, where reservations must often be made months in advance. Atlanta is rapidly becoming a center for high technology. A number of nationally known high-tech firms are headquartered in Atlanta, including Scientific-Atlanta (telecommunications systems), HBO & Co. (hospital software), Management Science America (IBM mainframe software), Hayes Microcomputer Products (personal computer software), and Microtest (personal computer software). Many of these high-tech firms have major facilities in Atlanta, including Lockheed-Georgia (12,500 employees), IBM (3,200 employees), AT&T Network Systems (3,000 employees), and Northern Telecom (1,400 employees). Several leading computer manufacturers perform research and development in Atlanta, including Control Data and Sperry. Georgia Tech's Advanced Technology Development Center attempts to attract high-technology firms to Georgia and provides low-cost space and advisory services to both start-up companies and established firms opening new laboratories.

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The School of Information and Computer Science maintains a vigorous program of research made possible through corporate support and government grants. Research ranges from theoretical studies that pave the way for tomorrow's computer systems to practical efforts that shape the systems of today.

ICS research can be divided into fifteen areas, which are described on the following pages. Although these areas span the field of information and computer science, most of them fall into three general categories: distributed computation, software engineering, and artificial intelligence. These are the three major directions of ICS research in 1988.

Distributed Computation
(see Computer Systems Organization, Programming Languages and Environments, Distributed Operating Systems, Computer Networks, Database Systems, Theoretical Computer Science)

The keystone of the School's research in distributed computation is the Clouds project. Clouds is a reliable distributed operating system that will serve as a testbed for research in distributed computation.

Research

Software Engineering
(see Software Engineering, Human Factors in Computer Systems)

Major projects include the design and construction of Motha (an advanced software testing environment) and the Software Test and Evaluation Project; both projects are conducted jointly with the Software Engineering Research Center.

Computer Systems Organization

Many different Single Instruction Multiple Data stream (SIMD) multiprocessors have been proposed and developed. However, comparatively little effort has been devoted to analyzing performance models or developing adaptable software tools for programming SIMD multiprocessors. Professor William Appelbe has developed a model for a wide class of SIMD architectures, together with a language for specifying SIMD algorithms, that allows the performance of SIMD algorithms and architectures to be evaluated. Work is currently in progress to complete a simulator and compiler for the SIMD model and language. Future plans include using the language to develop new algorithms and implementing the model architecture in VLSI.

Recent advances in VLSI technology have made possible the design and construction of very powerful parallel machines. When designing such a system, hardware is less of a problem than the accompanying software. Professor Aalaya Mathur's goal is to make powerful computers more easily usable by providing them with the capability of interacting with users in multiple natural languages and by providing a uniform programming environment. Such an environment should support the view that a program is an organized collection of communicating sequential processes. His approach combines basic elements of computer system architecture and natural language processing.

Machines with multilingual capability would be useful for many large organizations, including international corporations and governments; unfortunately, this capability is difficult to provide. Professor Mathur's approach is to develop language-independent methods for organizing, processing, and accessing information.

The need to develop software for processing large amounts of knowledge has led Professor Mathur to examine parallel machines with reconfigurable architectures (or some subset). He has concluded that none of the most popular parallel programming languages is suitable for programming such machines. He is currently studying the use of the Occam language for the programming of large arrays on parallel machines.

Programming Languages and Environments

Three ICS faculty members perform research in the area of programming languages. The research of two faculty (Richard Leliane and Mustafa Amanad) is closely related to the Clouds project (see "Distributed Operating System"). Professor LeBlanc's interests in Clouds include the development of language features and programming methodologies appropriate for the Clouds environment. He has supervised the design and implementation of the Aesulus language, which allows a program to define objects and actions. The features of Aesulus allow access to the capabilities provided by the Clouds kernel. Work is currently in progress to develop programming techniques that use the features of Aesulus to program replicated objects that can survive system crashes and other faults.

Professor Amanad is developing communication structures for distributed languages. He is particularly interested in structures that are suitable for system-level algorithms, such as those implemented as part of a distributed operating system. These algorithms often require multiscall communication; hence, it is a logical candidate for inclusion in a distributed language. Furthermore, current communication technologies support multicast communication directly in the network hardware. He is currently working on a communication structure that provides a natural context for language-level multicast communication. This research is closely tied to Professor Leliane's work in distributed operating systems, which is described under that heading.

Professor Appelbe is tackling the problem of introducing parallelism into programming languages. Although sequential programming constructs are well understood, there is little agreement about how parallelism should be introduced. Professor Appelbe has been actively involved in designing and implementing parallel extensions to existing algebraic programming languages; he is also interested in alternative approaches such as parallel functional and logic programming languages.
Software Engineering

ICS research in software engineering received a boost in the fall of 1986 with the establishment of the Software Engineering Research Center (see “Computer Science Research at Georgia Tech”). Much of the School’s software engineering research is conducted by faculty who are affiliated with the Center.

The director of the Software Engineering Research Center, Professor Richard DeMillo, is supervising two major software engineering efforts: the design and construction of the Motrica environment and the Software Test and Evaluation Project (STEP).

The Motrica environment is an integrated set of tools and interfaces that support the planning, definition, preparation, execution, analysis, and evaluation of tests of software systems. Motrica can be used for the earliest stages of software design and development through the later stages of system integration, acceptance testing, operation, and maintenance. Motrica has been designed to satisfy two primary criteria. First, the Motrica interfaces—particularly user interfaces—are high bandwidth. Second, the overall architecture imposes no a priori constraints on the size of the software systems that can be tested. As a consequence of the second requirement, the same architecture is able to service programs varying in size from individual modules of less than 100 source lines to fully integrated systems of more than 100,000,000 lines. The only indications of size or complexity that have to do with the Motrica architecture are the operating system cost penalties and performance delays inherent in manipulating massive executable objects. The key to this approach is to design an environment in which most primitive operations are performed as local transformations of executable objects. The ability to carry out local transformations efficiently allows the tester to conduct extremely thorough software tests using program mutation, a kind of software fault detection experiment. A by-product is the ability to conduct various coverage analyses as well as other systematic software tests. Motrica also promotes the use of heuristic tools for software testing. This feature allows the test procedures to be reduced to a set of well-understood and natural activities. Since Motrica supports tests of both very small and very large programs, the details of the tools that are actually invoked vary in power and scope. However, even very different tools can implement basic themes that are carried along throughout the several phases of testing.

Motrica is constructed using the ASET Bell Labs 8-bit interactive bitmap display terminal running under the control of a UNIX System V window manager called Flax. The host environment is a DEC VAX 11/780 running UNIX 4.3BSD; however, the architecture of Motrica enforces rehosting. Furthermore, explicit operations allow Motrica to spawn parallel and vectorized processes for execution by a CYBER 205 or other powerful parallel machine. The goal of STEP is to develop new policies and methodologies for use by the U.S. Department of Defense in the use and evaluation of software. Virtually all major defense systems contain computers as critical components; the testing of software is a key consideration for insuring the reliability of these systems.

Through the first two years of the project, Professor DeMillo’s group carried out an extensive evaluation of software testing practice. This effort culminated in a number of recommendations for modifying policy for software testing. The project is now developing methodologies and tools that allow implementation of these policies. STEP is partially funded by DARPA, the new DoD Software Technology Initiative.

Professor Richard LeBlanc is the SERC Research Program Area Manager for Tools and Environments. His research in this area includes the study of methodologies and tools for input prototyping and formal specification techniques for transformation-based software development. This rapid prototyping study is aimed at finding a consensus among the variety of viewpoints on prototyping represented in the research literature. It is planned that a definition of a set of tools that might be called “prototyping environments” will emerge from this study. Future efforts will then include development of such an environment. An alternative to the conventional approach to software development, sometimes called the “operational approach,” is based on constructing programs by applying transformations to specifications. The specifications used in this approach must be sufficiently rigorous so as to be unambiguous and executable by a suitable interpreter; thus the use of “operational” in the name. Professor LeBlanc is studying potential specifications languages and how they influence the set of transformations required to derive programs from specifications. Other work in software engineering is being performed by Professor William Applebe, James Burns, and Nancy Griffith.

Debugging multitasking applications programs for multiprocessors such as the Cray-XMP is notoriously difficult due to nondeterminism and the difficulty of tracing concurrent execution. Professor Applebe has developed a tool for static analysis and testing of parallel programs. The tool takes as input a source program (written in FORTRAN with explicit parallel extensions) and analyzes it to determine all classes of feasible execution paths that can cause potential bugs such as deadlocks or race conditions. Work is currently in progress to make the prototype more efficient and provide a better user interface. Future plans include adapting the tool for other programming languages, such as Ada, and investigating automatic parallelization of sequential programs.

Distributed Operating Systems

A current problem in distributed systems is that of combining multiple computer systems to provide a unified environment for use. The Clouds project, directed by Professors Partha Dasgupta and Richard LeBlanc, is tackling this problem by designing and building a reliable distributed operating system. The fundamental aim of the project is to provide a toolbox for the evaluation of techniques for constructing distributed systems.

Clouds is a global operating system; it allocates and manages all resources (processors, files, etc.) globally. No distinction is made between local and remote resources. Instead, decisions assigning processors to specific tasks are made on the basis of heuristics. Distributed data management is an important consideration for Clouds. The kernel provides highly reliable data management, simplifying the task for the operating system and application programs. The Clouds group is currently working on a prototype kernel for a cluster of VAX 11/780 systems.

The architecture supported by Clouds will provide object actions and objects. Actions, which are instances of abstract data types, provide the basis for consistency. Atomic actions are the basis for recovery. Actions help to categorize the state of system components after failures. The Clouds project is closely integrated with Professor LeBlanc’s projects. Work on the monitoring of distributed programs will facilitate the monitoring of distributed programs.
development of systems under Clouds. Clouds, in turn, will provide support for distributed programming languages. Another faculty member contributing to Clouds is Professor Mustaque Ahmad, who is designing communication protocols for the Clouds system. He is also developing strategies for supporting fault tolerance using object replication and for efficiently locating Clouds objects.

In another effort, Professor Ahmad is developing an operating systems level multicasting facility that will provide system calls that user processes can invoke to send and receive multicast messages. He is currently working on a multicast protocol and its implementation in UNIX. This protocol must deal with two problems. First, it must support message delivery to a group of processes that may execute on hosts connected to many networks. Second, the membership of a multicast group can change dynamically, and hence a distributed algorithm is needed to maintain the membership of a multicast group. More generally, Professor Ahmad is interested in the correctness and performance of distributed algorithms, fault-tolerance algorithms, and specialized algorithms for various classes of applications.

Computer Networks

With four faculty members (Professors Philip Erslow, Oliver Ibe, Mostafa Ammar, and Raymond Miller), computer networking is one of the School’s largest research areas.

During the past year, Professor Erslow has conducted an investigation of the performance of an Ethernet-type local area network. The objective of this project was to validate a CSMACD simulation model by making measurements on an operational network. One of the most important findings was that the performance of current instrumented equipment is not adequate to assess properly the performance of data communications systems or computer networks. Most of the existing instrumentation and test equipment (e.g., datacom and protocol analyzers) has been developed for the primary role of testing the functionality and execution of communication protocols. Special equipment has been developed during this project to perform these functions, and the availability of this equipment will greatly enhance both the educational and research effectiveness of our laboratories.

Another area of research activity is the investigation of flow control in network architectures. It is obvious that the effects of flow control are governed by the performance of many, if not most, data communications and computer network systems. However, the performance of most computer network flows over simple point-to-point circuits in the presence of errors is not well understood. The problem is complicated by the introduction of cascaded flow control mechanisms in data lines connected together in tandem. Our lack of understanding becomes even greater. The problem does not exist in one area. Of equal importance is the interaction of different flow control mechanisms at the various levels of a layered architecture. What are the results when flow control mechanisms are nested one inside another and then cascaded over separate lines that are connected together in series?

During the past year, work in this area has concentrated on the definition and development of two simulation programs: a data link simulator that includes the effects of errors in a single-layered flow control simulator that supports the study of nested flow control mechanisms in which each layer may use a different credit mechanism. An important aspect of this work will be validation against operational systems.

Of major significance to research in this area is the establishment of the Data Communications and Computer Networking Laboratory. A well-equipped instructional and research facility containing equipment covering the spectrum from analog and digital transmission systems to a complete multi-node, store-and-forward, packet-switched system.

Professor Ibe's research stems from the advent of integrated services digital networks (ISDN) and office automation, which require the integration of voice and data onto one network. He is interested in protocols for integrating voice and data on both local area networks and metropolitan area networks. So far, Professor Ibe has proposed transmission and flow control protocols for integrated voice and data local area networks.

he has also proposed an efficient medium-access control protocol for CATVtype metropolitan area networks. Current work includes investigating efficient routing and flow control algorithms for integrated voice and data long-haul networks. In addition to studying computer networking, Professor Ibe is applying such operations research tools as queuing theory and mathematical optimization theory to the performance evaluation of computer systems.

Professor Ammar's research concerns the issue of how to design a system to deliver information to a potentially large number of users. Because of the inherently centralized nature of such systems, the traditional center-oriented, one-to-one communication approach may place unnecessary constraints on the performance of the system. His research, therefore, considers the use of broadcast communication in both one- and two-way communication systems. For one-way systems, Professor Ammar has been able to demonstrate the optimality of a cyclic information-delivery approach and has proposed a heuristic procedure for the design of a near-optimal cyclic delivery sequence. For two-way systems, his analysis of the performance characteristics of systems using broadcast communication has shown the advantage of this approach.

In another project, Professor Ammar is analysing the performance of manufacturing systems with integrated control and communication functions. His work is motivated by the need to increase the efficiency of the manufacturing process. This need has prompted a great deal of interest in the use of flexible and automated manufacturing systems. As part of this trend, the manufacturing process is now viewed as integrating computers used for process control and monitoring. This, in turn, makes necessary the use of digital communication networks to allow the on-demand components of the system to interact.

Professor Ammar's work deals with systems in which the manufacturing process is externally controlled by computer-based equipment that communicates with the manufacturing system via a communication network. Messages from the manufacturing system to the control computers may contain data as well as other information about the progress of the manufacturing process. Based on this data, the computer sends instructions and other information that serve to modify the manufacturing process. In such a setting, the efficient operation of the manufacturing process will depend not only on the efficiency of the manufacturing system and control equipment, but also on the mechanisms used in the communication network. Administrator Ammar's goal is to model and analyze integrated manufacturing systems to understand the effect of various parameters on system performance.

As a first step, Professor Ammar has analyzed an externally controlled two-stage manufacturing system. His analytic results show the effect of the system parameters on system efficiency. One of the primary conclusions of this preliminary study was that the introduction of external control and communication functions can significantly affect the performance of manufacturing systems.

Professor Raymond Miller's research in parallel computation and synchronization includes the development of models for network protocols. The recognition of structure in protocols simplifies the analysis and design of communication protocols. With a previous doctoral student, he explored an approach based on a decomposition technique which expanded use of these techniques is underway. He is also investigating other formal techniques for protocol construction, especially the extension of the modeling techniques to provide more concise protocol specification.
Database Systems
Recent advances in computer hardware suggest many new ways to approach database problems. One such advance is the availability of machines with main memories large enough to contain an entire database. This arrangement would naturally make database access much faster but could also increase the vulnerability of the database to failure. Professor Nancy Griffith has been studying the issues involved in storing data reliably. Extending this work to main-memory databases would raise a number of questions. How should data replication be managed? Should copies be kept on slower devices, or should a larger number of copies be kept on multiple faster main-memory devices? Another question is how to control the units of work—the transactions—so that each is run to completion once and only once. A third question is how to organize the system history so that recovery from a system failure is possible. The usual method is to keep the history on a secondary storage device, which is much slower than main memory. Is this too slow for a main memory database, and if so, how should the history be kept? One alternative would be to use a stable form of main memory (this is yet another hardware advance that affects database techniques).

Another hardware advance that promises great improvements in database performance is the development of parallel computers. Since databases are intended to be used simultaneously by many different people, it seems natural to use parallel processors to access a shared database. The size of available parallelism, however, will be limited by traditional methods of controlling interference among different database users. Professor Griffith has recently developed methods to take advantage of available parallelism without permitting different users to interfere with each other. This work has raised a number of new questions involving the implementation of these methods and the optimization of their performance. A project is underway to investigate how to use one of these new techniques in the Clouds operating system.

VLSI Systems
Another class of database problems involves the database user. Professor G. Vijayan, who is developing design tools for high-level chip design, was instrumental in the development of one such tool, a PASCAL-like language for procedural specification of layouts. An important aspect of the language is that the user is not required to specify any metric values but instead describes only the topology of the circuit under design. He is currently at work on another design tool, a high-level interactive topological layout system that can be used from a Sun workstation. The system will allow a VLSI designer to draw a rough topological sketch of a module and its interconnections; the system then automatically produces an area-efficient physical layout. The system will allow hierarchical and parametric specifications of layouts. The design of such a system involves solutions to certain graph-theoretic problems concerning efficient layout for graphs. Tools such as these should lead to a significant reduction in the time required to design a VLSI layout. A key resource for VLSI research in VLSI systems is Georgia Tech's Microelectronics Research Center (see "Computer Science Research at Georgia Tech").

Theoretical Computer Science
Broadly speaking, theoretical computer science is concerned with the formulation of abstract models of computational processes and the study of properties of computation through these models. ICS research in theoretical computer science focuses on the problems of parallel computation and VLSI system design. A specialist in concurrent algorithms, Professor Gary Peterson has examined in the past such problems as mutual exclusion and resource control. More recently, he has been working on the design of efficient networks for parallel computation and efficient algorithms on networks as well as studying the comparative powers of concurrency synchronization mechanisms. He is also interested in other areas of theoretical computer science, including complexity theory and its relationship to information theory, models of VLSI computation, and alternation and related parallel models. Professor James Lumsa has long been interested in problems of synchronization and efficient communication among independent, parallel processes. One problem of particular interest is that of breaking symmetry in an initially symmetric network by cooperatively electing a distinguished processor. Recent work with Professor Peterson and a graduate student has investigated the problem of electing a processor in an asynchronous ring when the processors do not have distinct identifiers. Another problem of interest in the area of distributed systems is called the Byzantine agreement problem. A solution to this problem guarantees that all reliable processors agree on a common decision despite the malicious activity of a limited number of faulty processors. In a recent paper (co-authored with Dr. Nancy Lynch of MIT), Professor Lumsa examined a new variant of this problem, called the Byzantine firing squad problem, in which the reliable processors must execute a common action simultaneously despite the active interference of the faulty processors.
Professor Vijayan is also working on approximation algorithms for NP-complete problems (graph coloring in particular) and studying problems in computational geometry.

Professor Henk Verkerk is interested in complexity issues pertaining to parallel computation. He is studying abstract models of parallel computation and relationships among various parallel complexity classes, with the objective of understanding the nature of computations in these classes. Recently, he devised a new two-person pebble game to model synchronous parallel computations. In joint work with Dr. Martin Tompa of the IBM Thomas J. Watson Research Center, Professor Verkerk was able to obtain new characterizations for certain natural parallel complexity classes using this game model. The game abstraction provides a unifying framework for many parallel algorithms; the simplicity of the model helps to focus on the fundamental aspects of these computations.

Gary Peterson

A fifth member of the theory faculty is Professor Raymond Miller, who specializes in models of parallel computation. Such models provide a rich variety of approaches, techniques, and views of computational processes. Although his recent work focuses on network protocols (see "Computer Networks"), Professor Miller is interested in using parallel models in other application areas as well.

James Buma

Human Factors in Computer Systems

The objective of Professor Albert Badre's research in the human factors of computer systems is to identify and explore empirically the human factors that affect the design and operation of computer systems and the efficiency of the software development process. Professor Badre's latest work involves designing transferability of knowledge among novice users and the integration of human factors into the user-computer interface. Many software systems that claim to be "user-friendly" merely provide an interactive, menu-driven interface. While this is fine for novices, more experienced users find menus to be an obstacle to efficient use of the system. Some systems attempt to solve this problem by providing both a novice, menu-driven interface and an expert, command-driven interface. Unfortunately, the two modes of interaction are usually independent: experience gained through the use of menus does not help the user learn the commands needed for the expert interface. The two-level interface also fails on two other counts: it does not allow a smooth transition from novice to expert, and it does not acknowledge that a person can simultaneously be an expert user of some system functions but a novice user of others.

Professor Badre believes that a user interface should be designed so that a novice user can gradually develop into an expert through experience gained by using the system. This goal can be achieved by designing the interface so that the following conditions are met:

1. Each task can be performed in two different modes: the novice mode and the expert mode. The novice mode should depend on recognition memory strategies, such as menus, prompts, and instructional screens, while the expert mode should depend on free recall of a language of interaction.

2. It should be possible to learn the expert's vocabulary and syntax as a byproduct of practice as a novice. Linguistic continuity should be maintained across modes.

3. The expert's language of interaction should allow the bypassing of novice interactive strategies. It should also allow the introduction of new vocabulary and the generation of new sentences for "chunking" actions (grouping atomic actions into larger units).

Another area of research activity, motivated by distributed processing in heterogeneous environments, is the design of user-compatible transparent front ends. Professor Badre is experimenting with different strategies of command presentation and user selection. Professor Badre is also collaborating on a project to explore methods for assessing the use habits of system-specific audiences in both the laboratory and field environments. He is currently investigating an available editing system in order to compare it with an alternative user-oriented menu-driven prototype now under development. The long-range objective is to record, study, and evaluate the habits, language behaviors, practices, and recurring problems encountered by operators using various on-line off-line information processing and communication functions, such as actions, command systems, and communication systems.

James Buma

Albert Badre

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Artificial Intelligence

Organization and access of the knowledge needed for doing intelligent tasks is perhaps one of the hardest problems facing researchers in artificial intelligence. Professor Janet Kolodner's research group is concerned with the organization, retrieval, and acquisition of experience-acquired knowledge necessary for reasoning in both expert and common-sense domains.

As a first step, Professor Kolodner's group has designed CYRUS, a computer system that stores events from the lives of former Secretaries of State Cyrus Vance and Edmund Muskie and answers questions when queried in natural language. CYRUS is based on a human model, organizing and remembering events as people might do.

In current work, the group addresses the problems of how such a memory can be used in solving problems, how task competence changes through experience, and how experience enhances problem-solving capabilities. The ultimate goal of this research is to produce computer programs capable of reasoning in such a way that the program can adapt and improve over time.

The primary text for his research has been the Academic Counselling Experiment (ACE) system, a conversational program that simulates a faculty advisor interacting with students in tasks such as question-answering concerning course offerings, pre-registration, and establishing a plan of study, and explaining the curriculum. The focus of the ACE research has been on the control of the language-processing, reasoning, and memory-retrieval resources of an intelligent system to manage the tremendous complexity that appears in realistic conversational behavior. The directing idea has been to give an intelligent system its own internal goals, so that in some reasonable sense, it has a need to interact with its users. A current aim is to bring up a version of ACE that can interact with real students.

The main problems to be solved in the realization of robust language-using systems are not in language processing, per se, but in the design of the systems' knowledge base and the application of that knowledge in problem solving. A current focus of attention is in common-sense reasoning, an attempt to model how people use their knowledge of the world, including especially contingent reasoning rules, in their day-to-day activities.

An appealing model of this process is to view reasoning as a species of search, in which portions of a visual belief set are elucidated as the reasoner runs. Professor Cullingford is currently implementing a Best-First Reasoner, which attempts to apply both common-purpose and domain-specific meta-rules to select the currently most plausible reasoning chain to extend. The Reasoner is a resource of a simulated planner, a line monitor for a robot system attempting to navigate through an environment by using a safety street map.

The ICS artificial intelligence group currently includes ten graduate students. Programming is done in LISP on Symbolics LISP machines.
Cognitive Science

Cognitive science is a newly emerging discipline that combines techniques and approaches from the fields of artificial intelligence, linguistics, psychology, anthropology, and philosophy to attack problems in cognition (knowledge use and acquisition). In the 1970s and 1980s, a number of AI researchers began formulating new theories of human cognition. At the same time, the cognitive revolution was gathering momentum. Researchers in artificial intelligence and cognitive science are increasingly working with each other to find a common ground.

Parallel computation. Cognitive science at Georgia Tech may serve a boost in the near future—thanks to the School of Psychology, which is adding several new cognitive scientists to its ranks. The School of Psychology's new plans to hire several new cognitive scientists are an indication of the growing interest in the field of artificial intelligence.

Researchers in cognitive science include Professors Janet Kleinschmidt and Richard Cottrell and psychology postdoctoral fellow Julian Lancaster. While the artificial intelligence researchers at Georgia Tech have a growing interest in the area of problem-solving strategies, the goal of achieving a better understanding of the processes underlying the skills of solving ill-defined problems. These processes include both problem-solving strategies and strategies for acquiring and organizing the knowledge necessary for solving problems. The effective delineation of such processes would lead, on the one hand, to the development of computer programs that model expert solving of ill-defined problems, and on the other hand, to the computer extension of human information-handling and problem-solving capabilities. Professor Cottrell has been successful in introducing new techniques to delineate the representational structures in problem-solving protocols.

Computer Vision

Computer vision is an important area of robotics and flexible automation. As robot systems become more commonplace, the need for sophisticated vision systems will become critical. In recent years, there has been considerable interest in developing new vision techniques to deal with real-world objects.

Professor Pranas Zunde's long-term goal is the development of a workstation containing several robots that work in tandem. Such a workstation could be used to perform automatic inspection or assembly of parts. Research in this area is directed toward developing a computer vision system for robots to allow efficient interpretation of the visual data.

In the short term, Professor Zunde designs a system for three-dimensional data acquisition. The data gathered by the system constitutes a range map. Using these range maps, he will investigate several three-dimensional recognition techniques.

In another project, Professor Zunde is formulating visual representations for modeling dynamic events. This work is motivated by a robot's need to model the changing state of the world around it in order to interact adaptively with its environment. This model must encompass at least the fundamental notions of causality and Newtonian physics so that the robot can use prior states of the world to predict future states. As the actual states are realized, these predictions must be updated to reflect this new information, preferably making maximum use of the previous prediction in formulating the next. The model must make use of factors such as whether a body is free or constrained and whether it is rigid or deformable. Such a model cannot be developed without a suitable representation of the visual and other sensory signals received from the environment. These signals provide information about the state of the world such as location, orientation, velocity, and acceleration.
Information Science

Professor Frances Zunde works in information science to focus on the empirical foundations of the subject. He is attempting to identify the body of knowledge that can be derived from empirical observations of information phenomena and is representative of information science as a distinct scientific discipline. This work leads to hypotheses under study that include information value, relevance, aging of information, growth of knowledge, obsolescence, information decay, productivity of information sources, and information flow.

In another project, he is examining certain quantitative aspects of semantic coding in an attempt to determine the relationship between diversity of meaning and syntactic properties of words and morphemes in informative texts. He will test entropy maximization theory as well as other relevant theories for their capability to account for, explain, and predict empirical findings of the study. Finally, Professor Zunde will determine the feasibility of developing a comprehensive theory of semantic coding along the lines of Shannon's information theory, using the empirical results of the earlier investigation as test data. The study may have applications in areas such as information retrieval and the modeling and design of interactive computer systems.

Professor Zunde is also working in the field of pattern recognition, in which he is currently studying adaptive methods of feature extraction. Present methods for automatic extraction and selection of features from data for pattern recognition and classification are operationally limited to data types that seldom are of interest in real-life applications. One of the reasons for the limited use of present methods is their insensitivity to changes in the characteristics of patterns (i.e., input data). To overcome this limitation, Professor Zunde is examining adaptive systems of feature analysis and extraction, with emphasis on binary patterns and application of error-correcting coding techniques.

Professor Zunde's most recent project is a study of word association aids in information retrieval. He believes that the success of advanced or "intelligent" information systems depends on a large extent on our knowledge and understanding of the semantic aspects of the information processed. One of these aspects is the semantics of word associations, in the classical sense of stimulus-response studies. Professor Zunde is constructing information-retrieval aids based on word associations and testing their effectiveness in conjunction with traditional lexical aids (measures, semantic networks, etc.). He will then conduct a series of on-line searches with and without word association aids and evaluate the results in terms of user satisfaction.

Information Systems

Professor Vladimir Slameneck directs a five-year, $5.0 million effort to design and implement a national network of scientific and technical information services for the Arab Republic of Egypt. The major product of the first, completed phase of the program was the structured design of this sectorally oriented information network. The final phase, which is nearing completion, includes the development and implementation of these services involving, among others, the development of a distributed network of Egyptian databases, interactive searching of foreign databases, a document delivery system, a nationwide manpower training program, and the establishment of the legal and organizational superstructure to coordinate and govern this evolving national network.

Professor Slameneck's program addresses a number of R&D issues, including national portability of executive software, bilingual end-user software, uniform database design for full-text and tabular data, and a standard bilingual command language interface for databases of diverse content. The program is receiving international attention as a case study demonstrating innovative application of state-of-the-art information technology in developing countries. Professor Slameneck's work on the program was cited by the American Association for the Advancement of Science when it elected him a Fellow in 1983.

Computer-Supported Instruction

The IBM Computer-Supported Instruction Laboratory, operated by the School of ICS since 1984 under a joint study contract with IBM's Academic Information Systems Group, continues to pass milestones. The Laboratory's two classrooms, each containing a number of networked IBM PCs, have reached saturation, currently serving about 1,000 enrollments per quarter. The Laboratory supports courses in many academic areas, including English, modern languages, and philosophy, disciplines that are not traditional users of computers in instruction.

Philip Siegmund

Gus Baird

Vladimir Slameneck

John Gaida

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In addition to research performed within the School of ICS, students and other organizations on campus perform computer-related research and development.

Georgia Tech Research Institute

The Georgia Tech Research Institute (GTRI) is a nonprofit applied research organization that performs sponsored research for government organizations and private firms. GTRI employs over 900 researchers, including nearly 150 faculty, students, and consultants, in over 20 different locations, including over 70,000 square feet of lab space.

Microelectronics Research Center

The Microelectronics Research Center (MERC) was established in 1988 to coordinate integrated circuit research and development on campus. Under the direction of the Center, researchers focus on the research and development of advanced microelectronic devices, circuits, and systems. MERC operates within the School of Electrical and Computer Engineering and is supported by the NSF and other funding agencies.

Software Engineering Research Center

The Software Engineering Research Center (SERC) was established in 1990. It is one of the nation's largest centers dedicated to software engineering research and education. SERC conducts research in areas such as software design, development, maintenance, and testing.

US Army Institute for Research in Management Information and Computer Science

Established in 1977, the U.S. Army Institute for Research in Management Information and Computer Science (ARMS) conducts research, develops, and supports research and development involving the Army's management information systems. Some SERC faculty members participate in joint projects with ARMS.

Academic departments

Several academic departments at Georgia Tech perform computer-related research, including Industrial and Systems Engineering, Electrical Engineering, Mathematics, and Civil Engineering. A number of ICS graduate students work as research assistants in these departments.

Publications

July 1985 to June 1986


Ammer, M.H.; see also Dyser, H.O.; and Wong, J.W.


Undergraduate

The undergraduate program in information and computer science leads to the degree of Bachelor of Science in Information and Computer Science. Each student chooses a course of study that prepares him or her for a professional career in one of the major areas of information and computer science or for research-oriented graduate study. This program has been accredited by the Computing Sciences Accreditation Board, Inc. In addition to the standard four-year program, the School offers a five-year cooperative plan that combines industrial experience with classroom study. For further information and application forms, write to:

Director of Admissions
Georgia Institute of Technology, Atlanta, Georgia 30332-0230

Graduate

The School offers programs of study leading to the M.S. and Ph.D. in Information and Computer Science. Students holding a bachelor's degree in computer science or other quantitative fields may be admitted to the M.S. degree program. The M.S. program accommodates students with a variety of career objectives, including technical and management positions in industry and government.

The doctoral program prepares exceptionally qualified students for research, academic, and policy-level management careers. Students applying for admission to the doctoral program must demonstrate evidence of exceptional scholastic ability, intellectual creativity, and research motivation. Further information and application forms may be obtained by writing to:

Dr. Edward F. Rouhani
Assistant to the Director
School of Information and Computer Science
Georgia Institute of Technology, Atlanta, Georgia 30332-0280

The financial aid available to graduate students in the School of Information and Computer Science is listed below. Other kinds of financial assistance are offered by Georgia Tech, e.g., Veterans Administration Program, work-study, state loans, National Direct Student Loans, and scholarships. Information on these is available from:

Director of Financial Aid
Georgia Institute of Technology, Atlanta, Georgia 30332-0460

Graduate Opportunities with Research Students

The CIMS Program

Georgia Tech offers graduate students in selected disciplines (including CIMS) the opportunity to participate in the innovative Computer Integrated Manufacturing Systems (CIMS) program. This interdisciplinary program allows students to develop and solve problems of computer applications in manufacturing. The CIMS program features a combination of multidisciplinary coursework, laboratory experiences, and interaction with industry. Students who complete the program receive a certificate documenting their experience in CIMS. Graduate assistantships are available for highly qualified CIMS participants.

More information about the CIMS program can be obtained from:

Mr. Edward F. Rouhani
Assistant to the Director
School of Information and Computer Science
Georgia Institute of Technology, Atlanta, Georgia 30332-0280

Programs

Financial Aid for Graduate Students

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Director of Financial Aid
Georgia Institute of Technology, Atlanta, Georgia 30332-0460

Graduate students are eligible for the Graduate Cooperative Program. Information about this program is available from:

Directors, Graduate Cooperative Program
Office of Graduate Studies and Research
Georgia Institute of Technology Atlanta, Georgia 30332-0265

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School of Information and Computer Science
Georgia Institute of Technology, Atlanta, Georgia 30332-0280

Graduate Teaching Assistantships

Part-time employment (usually one-third or half-time at a corresponding fraction of the full-time rate between $20,000 and $25,000 for twelve months), plus waiver of all tuition and fees. Duties consist of classroom and laboratory assistance, including instruction under supervision of faculty members.

Graduate Research Assistantships

Part-time employment (usually one-third or half-time at a corresponding fraction of the full-time rate between $20,000 and $25,000 for twelve months), plus waiver of all tuition and fees. Selection is based on the applicant's ability to contribute to research projects of the School. Normally open only to Ph.D. students.

Regents' Opportunity Scholarships

Stipends of $10,000 for twelve months plus waiver of tuition and fees for one year. The award can be extended for two additional years, based on the School's evaluation of the student's academic performance and research potential. Students must maintain a minimum GPA of 3.5.

Out-of-state Tuition Waivers

Awarded by the Dean of Graduate Studies upon recommendation of the School. Selection is based on academic performance.

Graduate Research Assistantships

Part-time employment (usually one-third or half-time at a corresponding fraction of the full-time rate between $20,000 and $25,000 for twelve months), plus waiver of all tuition and fees. Selection is based on the applicant's ability to contribute to research projects of the School. Normally open only to Ph.D. students.

Current Doctoral Students

Nancy K. Carson
Artificial intelligence
Mary Jone Caseley
Raymond C. Chen
Operating systems, systems software
Xian Cheng
Tao: Petting systems and their applications in metropolitan area networks
Advisor: Oliver C. Be
Suman V. Cherugu
Operating systems, database systems
Stephen D. Crawford
Computer graphics, computer networks
David A. Crick
Programming languages, natural language processing, algorithms
Martin H. Davis, Jr.
Software engineering, computer security
J. Daniel Gaubert
Topic: Garbage collection in networks
Advisor: Richard J. Leblanc
Luke Lin
Theoretical computer science
Gilbert M. Lundy
Topic: Motif and evolutionary analysis
John C. Prosser
Programming languages, theoretical computer science, computer security, data encryption
A. Dava Rice
Fractal geometry
Theoretical computer science
George T. Tufan, Jr.
Concurrent processing
Marston E. Gamba
Intelligent computer-aided instruction, expert systems
Geoffrey D. George
Artificial intelligence, non-procedural languages, computer algorithms
Welsh, T. Green
Computer networking, operating systems, artificial intelligence

Mark A. Graves
Artificial intelligence
John D. Guthele
Elise M. Hill
Topic: Conceptual interaction
Advisor: Richard E. Cullingford
Takai D. David Ho
Yang K. Hau
Expert systems
R. Dale Johnson
Artificial intelligence
Mohammad Fadli
Database systems
Distributed systems
Carson E. Kilgore
IBM Fellowship, 1990
Edward W. Kreuser
Database systems, software engineering, software testing, system architecture
Chung-Cheng Lin
Topic: The design of a distributed debugger for action-based object-oriented programs
Advisor: Richard J. Leblanc
Luke Lin
Theoretical computer science
Michael D. Lundy
Topic: Format methods for specification and verification (design and analysis) of computer network protocols
Advisor: Raymond E. Miller
Allaoua Naimr
Database systems
W. E. Williams, Jr. (President's Fellowship, 1990-91)
Computer networks and communications

Joe D. Martin
Artificial intelligence
Rhonda J. Martin
Software engineering, software testing, software metrics
Karen M. Miller
Natural language processing, database systems
J. Morgan Morris (President's Fellowship, 1989-90)
Topic: The effects of interaction factors in the transition from menus to commands
Advisor: Albert N. Badie
Magdi Morali
Topic: The design of an object-based database for a reliable distributed computing system
Advisor: Pratya Dalgity
John H. Muller
Probability theory and algorithms
A. Jeff Offutt
Topic: Software testing environments
Advisor: Richard A. DeMillo
Stephen B. Oden
Topic: Software specialization
Advisor: Richard L. Leblanc
Kee H. Park
Huijun Qin
Thao Rangangjen
Cognitive science, artificial intelligence
Michael A. Redmond
Artificial intelligence, cognitive science
Laurene Hegre Reuter
Computer graphics, human factors
C. Ray Russell
Topic: Effects of withholding information and task requirements on the design of human-computer interfaces
Advisor: Albert N. Badie