DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

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University at Buffalo
The State University of New York

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About the photos

Front Cover This illustration is built from a figure by Assistant Professor Jinhui Xu who is researching geometric techniques and optimization methods to develop algorithmic solutions in biomedical applications (design: Sassy Graphics, Buffalo).

Back Cover The Department of Computer Science and Engineering at UB maintains a vigorous research environment. Top to bottom: CEDAR's UK group works on pattern recognition for address interpretation for British mail. Teaching faculty Bina Ramamurthy and Helene Kershner support the teaching mission. The Director of CEDAR, Hari Srihari, and the Director of CCR, Russ Miller, engage numerous collaborators in innovative research. SNeRG researchers focus on knowledge representation and reasoning. Reaching out to industry, Chunming Qiao (right) and Bharat Jayaraman (center) chat with alumni Bill Styslinger (photos: J. Braswell).

www.cse.buffalo.edu

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COMPUTER SCIENCE AND ENGINEERING

Welcome

It is a pleasure to welcome to you the latest research brochure of the Department of Computer Science and Engineering (CSE). The Department was brought together in 1998 when faculty members in Computer Science joined with Computer Engineering faculty. The merger has been smooth, and we are in a phase of growth and exciting developments. In the last two years, we hired six tenure-track faculty members in a very competitive market. The CSE Department presently has 24 tenured/tenure-track and seven teaching faculty members. Our faculty includes AAAI, ACM, and IEEE Fellows, as well as NSF CAREER and ITR grant awardees. Our faculty are experts in their fields, serving on the editorial boards of some 30 reputable journals.

This brochure presents a sampling of our faculty research projects. CSE faculty interests are largely experimental, applied, and interdisciplinary in nature. We work in multimedia databases, computational science, theory and algorithms, pattern recognition, programming languages, computer networks, artificial intelligence, e-commerce, computer vision, information visualization, VLSI, and computer security. Our faculty are also affiliated with the Center for Computational Research, the Center for Cognitive Science, the Center of Excellence in Document Analysis and Recognition, and the National Center for Geographic Information and Analysis. In addition, CSE faculty plan to play a key role in New York State's planned Center of Excellence in Bioinformatics.

In the last two years, the CSE Department has had tremendous success in research funding, with individual NSF grant awards totaling over $3 million. Every CSE faculty member (except our new recruits) has an active grant. This year, a group of CSE faculty members received a $1.6 million research infrastructure award from NSF. The Department has averaged $4.5 million in annual research awards for the past several years. In a recent NSF survey of Ph.D. granting schools, we are ranked 26th in total research expenditures in computer sciences.

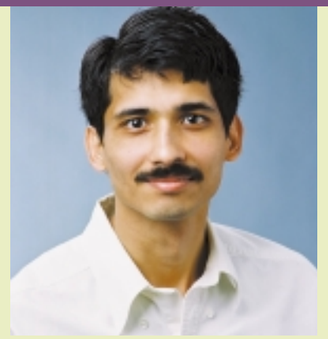
The CSE Department offers degree programs at the bachelor's, master's, and doctoral level, and we currently have over 1200 undergraduate majors and over 200 graduate students, nearly half of whom are in the Ph.D. program. Our students come from all over the globe, and we are proud of the cultural diversity of our Department.

Last but not least, the University at Buffalo, or UB as it's known, is New York's largest and most comprehensive public university. As the second largest city in New York State, Buffalo is the hub of a metropolitan area with a population over a million. University life is enriched by scenic, recreational, and cultural opportunities in the city, suburbs, and the neighboring Niagara and Metro Toronto regions.

I hope you enjoy reading this brochure, and I look forward to hearing from you.

Bharat Jayaraman
Professor and Interim Chair

Our Award Winning Scientists



Ashim Garg
National Science
Foundation
CAREER Award

Deborah K. W. Walters
ACE fellowship

Shambhu Upadhyaya
IBM Faculty
Partnership Award

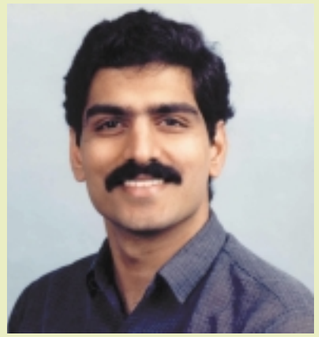
Stuart C. Shapiro
AAAI Fellow

Our Award Winning Scientists

Aidong Zhang
National Science
Foundation
CAREER Award

Alan L. Selman
ACM Fellow

Sargur N. Srihari
SUNY Distinguished Professor
IEEE Fellow



Venugopal Govindaraju
ICDAR Young
Investigator Award

Jinhui Xu
IBM Faculty
Partnership Award

Our Department

Left to right:
Aidong Zhang,
Bill Rapaport,
Venu Govindaraju,
Jan Chomicki,
Ashim Garg

Computer Science began at UB in 1967. Currently, our faculty includes 24 tenured and tenure track faculty, six research and adjunct faculty, and seven teaching faculty. We have a technical and administrative support staff of 12. Graduate students take a wide variety of courses, and have the opportunity to participate in groundbreaking research, to teach, to attend research group meetings, to serve on department committees, and to participate in internships in many fields and locations. Our student population is very diverse in geographic origin.

The Department provides state-of-the-art computer education and training to all students at UB to help them reach the knowledge and ability required by their major. Because of this commitment, CSE employs a top quality teaching faculty with professional strengths and career commitment to undergraduate education.

We also reach out to industry to be a resource for computing knowledge in Western New York. Industry short courses, colloquia, advisory and consulting relationships are some of the methods we use to share our expertise with the University, the region, and the state, as are appropriate for a department in a State University.

Top left: Xin He
Right, clockwise from left: Hung Ngo,
Jinhui Xu, David Pierce, Svet Braynov,
Ken Regan, Bina Ramamurthy, Ram Sridhar

Our Faculty

Faculty in the Department of Computer Science and Engineering are actively engaged in research in a broad range of areas. This index provides a quick reference to their individual research interests. Descriptions of research areas, research groups, and projects begins on page seven.

The Faculty and Their Research

- Sviatoslav Braynov, Assistant Professor, Ph.D., Russian Academy of Science 1998. Ecommerce, multiagent systems, artificial intelligence
- Jan Chomicki, Associate Professor, Ph.D., Rutgers 1990. Logical foundations of databases; database integrity; data integration; temporal, spatial, and spatiotemporal databases
- Ashim Garg, Assistant Professor, Ph.D., Brown 1996. Information visualization, graph drawing, computational geometry
- Venugopal Govindaraju, Associate Professor, Ph.D., University at Buffalo 1992. Pattern recognition
- Xin He, Associate Professor and Director of Graduate Studies, Ph.D., Ohio State 1987. Parallel algorithms, combinatorics, graph algorithms, graph drawing
- Bharadwaj Jayaraman, Professor and Interim Chair, Ph.D., Utah 1981. Programming languages and environments
- Nihar Mahapatra, Assistant Professor, Ph.D., Minnesota 1996. Parallel and distributed computing, computer architecture, VLSI
- Russ Miller, Professor, Ph.D., SUNY at Binghamton 1985. Parallel computing, computational geometry, computational crystallography
- Hung Quang Ngo, Assistant Professor, Ph.D., Minnesota 2001. Networks, algorithms, combinatorics
- David Pierce, Assistant Professor, Ph.D., Cornell 2001. Natural language processing, information retrieval and extraction, programming languages
- Chunming Qiao, Associate Professor, Ph.D., Pittsburgh 1993. Networks, parallel and distributed processing, optical and wireless communications, traffic engineering in Internet and distributed processing
- Anthony Ralston, Professor Emeritus, Ph.D. MIT 1956. Discrete mathematics, mathematics education
- William J. Rapaport, Associate Professor, Ph.D., Indiana 1976. Artificial intelligence, computational linguistics, cognitive science, philosophical issues of computer science
- Kenneth W. Regan, Associate Professor, Ph.D., Oxford 1986. Theoretical computer science
- Peter D. Scott, Associate Professor and Director of Undergraduate Studies, Ph.D., Cornell 1970. Controls, signals, and systems
- Alan L. Selman, Professor, Ph.D., Penn State 1970. Complexity theory

Clockwise from top: Hari Srihari, Alan Selman, Bharat Jayaraman, Russ Miller

Our Faculty

- Stuart C. Shapiro, Professor, Ph.D., Wisconsin-Madison 1971. Artificial intelligence, computational linguistics, cognitive science, knowledge representation, reasoning, natural-language understanding and generation
- Ramalingam Sridhar, Associate Professor, Ph.D., Washington State 1987. Computer architecture, VLSI systems
- Rohini K. Srihari, Associate Professor, Ph.D., University at Buffalo 1991. Multimedia information retrieval, multimodal interfaces, computational linguistics, context-based decision
- Sargur N. Srihari, Distinguished Professor, Ph.D., Ohio State 1976. Artificial intelligence, spatial knowledge representation and reasoning, computer vision
- Shambhu Upadhyaya, Associate Professor, Ph.D., Newcastle (Australia) 1987. Information assurance, dependable computing, distributed systems, VLSI testing
- Deborah K. W. Walters, Associate Professor, Ph.D., Birmingham (England) 1980. Computational vision, cognitive science, neural networks, visual perception, parallel processing
- Jinhui Xu, Assistant Professor, Ph.D., Notre Dame 2000. Computational geometry and algorithm design
- Aidong Zhang, Associate Professor, Ph.D., Purdue 1994. Distributed database systems, multimedia database systems, digital libraries, data mining, content based retrieval, bioinformatics

Teaching Faculty

- Carl Alphonce, Teaching Assistant Professor, Ph.D., British Columbia 2000. Computational linguistics, parsing, natural-language syntax
- Helene Kershner, Lecturer and Assistant Chair, M.S.E., Pennsylvania 1974. Computer literacy, software engineering
- Kris D. Schindler, Teaching Assistant Professor, Ph.D., University at Buffalo 2001. Computer Architecture, VLSI Systems, networking
- Barbara A. Sherman, Teaching Assistant Professor, Ph.D., University at Buffalo 2001. MIS concerns in information systems technology assessment
- Bina Ramamurthy, Teaching Assistant Professor, Ph.D., University at Buffalo 1997. Object oriented frameworks, distributed systems, pervasive computing
- Philip R. Ventura, Lecturer, M.S., University at Buffalo 2000. Instructional techniques, instruction in programming languages

Research and Adjunct Faculty

- Raj Acharya, Research Professor, Ph.D., Minnesota 1984. Multimedia computing, image processing/vision, medical imaging
- Laurence Boxer, Adjunct Professor, Ph.D., Illinois at Urbana-Champaign 1976. Parallel algorithms
- Victor Demjanenko, Adjunct Assistant Professor, Ph.D., University at Buffalo 1983. Communications systems, digital signal processing
- Herbert Hauptman, Adjunct Professor, Ph.D., Maryland 1955. X-ray crystallography
- Henry Hexmoor, Research Assistant Professor, Ph.D., University at Buffalo 1996. Multiagent systems
- Jeannette Neal, Research Associate Professor, Ph.D., University at Buffalo 1985. Natural-language understanding

Multimedia and Database Systems

The rapid expansion of the Web and the emergence of digital libraries have generated tremendous interest in multimedia information processing. Research in infrastructure for supporting large-scale, distributed multimedia libraries includes multimedia databases, efficient indexing, transmission, and networking issues. The incorporation of multimedia database systems will improve the quantity and quality of information manipulated by computer users in medicine, computer aided design, and information retrieval. The area of intelligent multimedia content analysis and retrieval techniques is an emerging discipline. Techniques for representing and extracting semantic information from media such as speech, images, and video are required. Related research in database systems involves the design and implementation of new query languages and user interfaces, driven by the needs of novel applications.

While available information retrieval techniques rely on human coding of semantic content, Zhang's intelligent content analysis analyzes images automatically. The picture analyzed depicts Bell Hall, home to the the main office of the Department of Computer Science and Engineering on UB's North Campus.

Faculty

- Jan Chomicki (Associate Professor)
- Aidong Zhang (Associate Professor)

Laboratories and Research Groups

Multimedia and Database Research Group
Director: Aidong Zhang
http://www.cse.buffalo.edu/DBGROUP/

Research in this area involves representation, indexing, transmission, retrieval and presentation of multimedia in a distributed environment, content-based retrieval, data mining, and bioinformatics.

MultiStore Research Group
Director: Aidong Zhang

MultiStore is a storage infrastructure project to construct, manage, and store multidimensional data sets. The project will carry out geographic imaging research, bioinformatic research, pharmacogenomic research, and basic research on large scale data sets and information visualization. Collaborators include David Mark, Director of the NCGIA, Nobel laureate Herbert Hauptman, and Norma Nowak, Director of the DNA Microarray Facility at the Roswell Park Cancer Institute.

Logical Foundations of Databases
Research Group
Director: Jan Chomicki

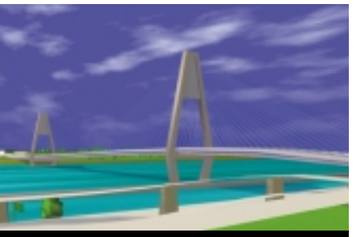
This research applies formal, logic-based methods to new, database applications. The research deals with data models, query languages, integrity constraints, and data integration. Specific projects include: consistent query answers in inconsistent databases, inconsistency resolution, querying with preferences, policy management, and spatiotemporal databases.

PROJECTS

NetMedia
Consistent and robust retrieval, transmission and presentation of multimedia data in distributed multimedia database systems

NetView
Content-based image retrieval system

Data Mining and Bioinformatics



PROJECTS

SnB
http://www.hwi.buffalo.edu/SnB/

Peace Bridge
http://www.ccr.buffalo.edu/peacebridge.htm

Buffalo Niagara Medical Campus
http://www.ibcdigital.com

Alive on the Grid
http://www.ccr.buffalo.edu/videos/alive.htm

Factory Design
http://www.vrlab.buffalo.edu/

Virtual Site Museum
http://pluto.fss.buffalo.edu/classics/htm/UBVirtualSiteMuseum/projects.htm

High Performance Computing/ Computational Science

Computational Science is an emerging discipline that unites computer science and mathematics with disciplinary research in biology, chemistry, physics, and other applied and engineering fields. It is already being called the third science, complementing theoretical as well as laboratory science. A major focus of computational science is the knowledge and techniques required to perform computer simulation. The importance of simulation can be found in "grand challenge" problems in areas such as structural biology, materials science, high-energy physics, economics, fluid dynamics, and global climate change, to name a few.

Faculty

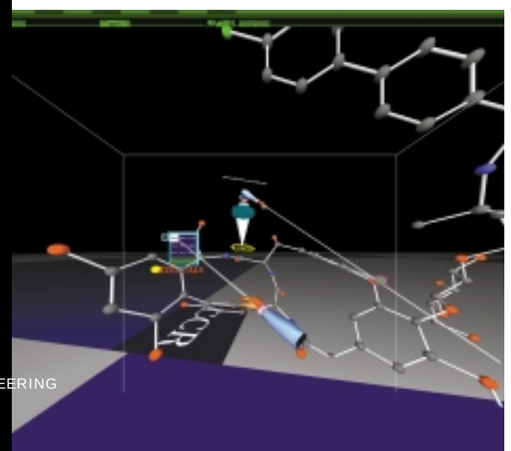
- Herbert Hauptman (Adjunct Professor)
- Russ Miller (Professor)

Laboratories and Research Groups

Shake-and-Bake (direct methods in X-ray crystallography for determining molecular crystal structures)
Director: Russ Miller
http://www.hwi.buffalo.edu/SnB

Center for Computational Research (CCR)
Director: Russ Miller
http://www.ccr.buffalo.edu

CCR is one of the leading academic super-computing centers in the country. With its SGI Origin2000, IBM SP, Sun cluster, and various Intel clusters, the Center supports computationally intensive research and high-end visualization at UB.



The *SnB* Collaboratory is an immersive 3-D collaborative environment currently in development and testing. It allows scientists all over the world to communicate in a virtual lab using hardware from high-end CAVEs® to workstations. The scientists can work synchronously or asynchronously on the same molecular structure in real time.

This improved communication allows scientific discovery at an increased rate as well as the possibility of working with scientists from multiple facilities.

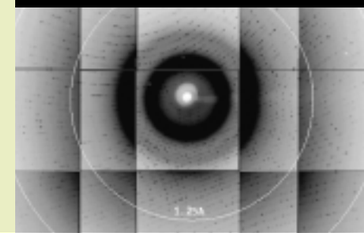
SnB

SnB is a computer program based on *Shake-and-Bake*, a dual-space direct-methods procedure for determining crystal structures from X-ray diffraction data. It represents a major breakthrough in the size of structures amenable to solution by direct methods. Prior to *SnB*, direct methods were able routinely to solve structures with 100 or so atoms. *SnB* can be used to apply direct methods to structures containing at least 2000 atoms. Such an accurate comprehension of molecular structures means that better and more targeted drugs can be developed to meet medical problems. *SnB* has already proven to be a critical first step in determining structures containing tens of thousands of atoms.

SnB can conveniently be run in parallel on multiple processors for faster throughput.

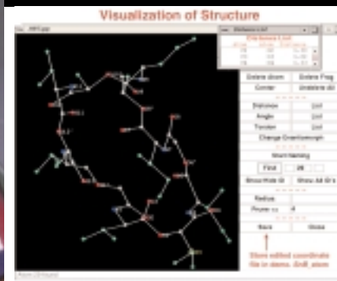
The direct-methods phasing algorithm is based on continually minimizing an objective function by alternating phase refinement with the application of real space constraints.

Crystals are isolated (above). X-ray diffraction patterns are generated (below).



The algorithm enables an accurate 3-D construction of the molecule.

The molecule can be explored with immersive visualization.



The current version, *SnB* v2.1, provides a graphical user interface for (i) computing normalized structure-factor magnitudes, (ii) running the main *Shake-and-Bake* phasing algorithm, and (iii) visualizing and editing the resulting molecular structure.

Alan Selman's research is concerned with properties of complexity classes, with relationships between classes, and with identification of properties of problems that affect their computational complexity. He has focused on several areas:

- Average case complexity, which provides mechanisms for classification of computational problems according to average use of resources, rather than worst-case usage
- Complexity theoretic underpinnings of public-key cryptography, including research on promise problems and complexity of classes of partial functions
- Polynomial-time-bounded reducibilities
- P-selective sets, which are an important tool for studying reducibilities and function classes
- Self-reducibility, which tends to lower complexity

Faculty

- Alan L. Selman (Professor)
- Kenneth W. Regan (Associate Professor)

Complexity Theory

Complexity theory is a mathematical discipline that classifies computational problems by relative difficulty and measures the computational resources needed to solve them. It explains why certain problems have no practical solutions and helps researchers anticipate the difficulties involved in solving problems of certain types. The classification is quantitative and investigates both the resources that are necessary to solve a problem called *lower bounds* for the problem and the resources currently known to be sufficient called *upper bounds*. In general, complexity theory deals with the quantitative laws of computation and reasoning. For this reason, complexity theory concerns issues and problems of direct interest to many other disciplines as well.

Ken Regan's research focuses on the obstacles to proving non-trivial lower bounds in complexity theory. Motivated by the fact that virtually no super-linear, let alone super-polynomial, time lower bounds are known for practical problems, part of Regan's work has developed the less-attended theory of linear-time classes. Regan has obtained super-linear lower bounds on time or circuit-size for some problems under certain restrictions. Currently, Regan is pursuing a mathematical approach to breaking barriers to proving super-polynomial lower bounds. Regan's work includes:

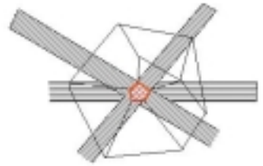
- Linear time computation and super-linear lower bounds
- Polynomial ideals and algebraic geometry as tools for lower bounds
- Mathematical logic for analyzing provability and characterizing complexity classes
- Complexity-bounded measure theory
- Fixed-parameter complexity theory

Design of Algorithms

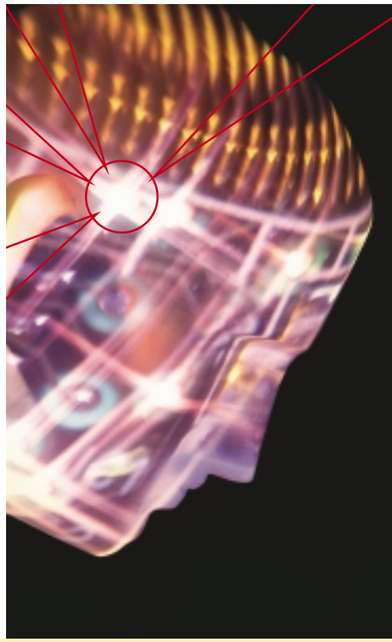
Design of algorithm studies methods and techniques used to develop efficient algorithms. The design of efficient algorithms is often a critical first step in solving problems in many areas. Depending on the model of computation or computer platform that is required for an application, one might draw on algorithmic research in specific subareas. Several CSE faculty members are involved in algorithmic research.

Faculty

- Russ Miller (Professor)
- Roger He (Associate Professor)
- Ashim Garg (Assistant Professor)
- Hung Ngo (Assistant Professor)
- Jinhui Xu (Assistant Professor)



A geometric algorithm by Jinhui Xu configures a set of optimal radiation beams to destroy brain tumors.



PROJECTS

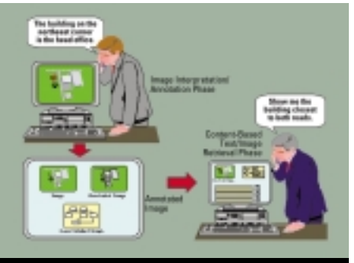
GRAPH ALGORITHMS (HE, NGO)
Many practical application problems can be modeled by graph problems. With recent developments in computer science (such as the Internet and networking), many new problems arise and create new research opportunities.

PARALLEL ALGORITHMS AND ARCHITECTURES (HE, MILLER)
Since the computational power of a single processor is limited, large-scale problems require multiprocessor machines. The study of parallel algorithms and architectures is concerned with the design and implementation of efficient techniques and strategies to solve problems on machines in which multiple processors are connected.

GRAPH DRAWING (GARG, HE)
Graph drawing deals with the problem of constructing two- and three-dimensional visualizations of graphs. A good visualization of a graph has several important properties, such as few edge-crossings, small area, good screen-ratio, and few edge-bends. This field focuses on developing time-efficient algorithms for constructing good visualizations of graphs.

COMPUTATIONAL GEOMETRY (MILLER, XU)
Computational geometry is a discipline concerned with the design, analysis, and implementation of efficient algorithms for solving problems by exploiting their geometric and combinatorial structures. Since many problems can be modeled by a set of geometric objects, such as points, curves, surfaces, hyperplanes, and polyhedra, geometric properties often lead to provably good algorithms.

GROUP TESTING ALGORITHMS (NGO)
Group testing dates back to World War II. Algorithms are derived to identify a set of "positives" in a large population of given items, assuming some mechanism exists that indicates if a pool of items has at least one positive. Direct applications of group testing algorithms include DNA-library screening, multiple access control, and mining association rules. Fundamental problems in group testing relate to mathematical disciplines like combinatorics, extremal set theory and algebra, making research on group testing very fruitful.



Multimedia information retrieval
http://www.cedar.buffalo.edu/~rohini

"Show & Tell" is a multi-modal system that combines speech and deictic input to perform image annotation and retrieval, e.g., labeling buildings and regions in aerial photographs. Image interpretation is guided by constraints obtained from the verbal description. Information extraction and natural language understanding techniques are used to process the text. Once information has been extracted, linked and consolidated, applications such as question answering from multimedia documents are enabled.

Dr. Rohini Srihari has been recognized by Infotech Niagara and by Pan Am 2001 for her innovations in image and web content retrieval.

Pattern Recognition

Pattern recognition is the study of methods and algorithms for putting data objects into categories. While classical pattern recognition techniques are rooted in statistics and decision theory, the machine learning paradigm is commonly used to design practical systems.

Machine Learning

Machine learning is a method of programming computers where, instead of designing the algorithm to explicitly perform a given task, the machine is programmed to learn from an incomplete set of examples. There are several different machine learning paradigms, such as the naive Bayes rule, artificial neural networks, genetic algorithms, and decision tree learning.

Data Mining

Data mining is the extraction of "nuggets" of information from structured databases. Algorithms for data mining have a close relationship to methods of pattern recognition and machine learning. Information extraction is the task of processing unstructured data, such as free-form documents, Web-pages and e-mail, so as to extract named entities such as people, places, organizations, and their relationships.

Faculty

- Sargur N. Srihari
- Venugopal Govindaraju
- Rohini Srihari

Laboratories and Research Groups

Multimedia Information Retrieval Research Group
Director: Rohini Srihari
http://www.cedar.buffalo.edu/~rohini

Center of Excellence for Document Analysis and Recognition (CEDAR):
Director: Sargur N. Srihari
http://www.cedar.buffalo.edu/projects.html

CEDAR performs research concerning scanned images of documents for the purpose of intelligent interpretation. Current supporters include the United States Postal Service, Lockheed Martin Federal Systems, and other corporations.

Individuality of Handwriting

We routinely validate documents with handwritten signatures. We do this because we presume that variability in one person's writing is less than the variability from writer to writer. To test the hypothesis that everyone writes differently, CEDAR researchers use machine learning algorithms to recognize handwriting from scanned documents, based on attributes characteristic of handwriting—line separation, slant, character shapes, and so forth. The work provides scientific support for admitting handwriting evidence in court.

To Collect Data

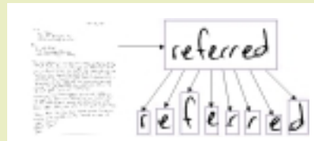
Samples from 1,000 writers are scanned and digitized, and line images are segmented. A feature vector is made up of sets of measurements for each sample. There are 512 binary microfeatures—in gradient, structure, and concavity—for each sample.

To Validate Individuality

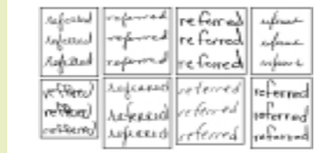
- The Verification Model: Are two documents the work of the same writer? CEDAR scientists can verify that one document was written by the writer of another document with multivariate statistical analysis of computational features. Classification is done using an artificial neural network trained using backward error propagation. Performance using only character level features is 98%.
- The Identification Model: Can the author be assigned from 1000 known writers? In this case the goal is to identify the writer of a document from among many writers from whom there are samples. In these cases, the computational features of the document in question are determined and compared to those of 1000 prototypes using the nearest neighbor rule.

Conclusions

Verification and Identification models are both useful in different circumstances. To demonstrate individuality of handwriting for legal purposes, both models can make that case, but the verification model can be parameterized corresponding to the number of writers considered, while the identification model cannot. The verification model can be applied repeatedly considering one writer at a time to yield identification. The verification model has statistical generality.

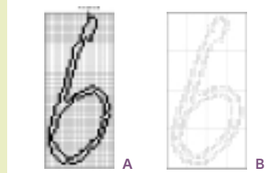


1000 writers write the same text, and their work is scanned and digitized. Word images are segmented from line images, and characters are segmented from words.



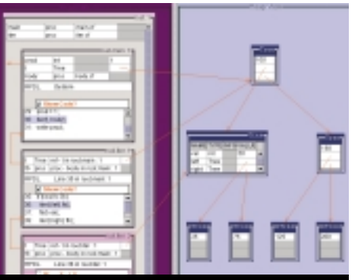
Eight writers write the same word three times as examples of within-writer and among-writer variation.

Macrofeatures at the line level include connectivity.



The segmented character is identified by 21 discriminating features used by document examiners. CEDAR scientists use computational features—those that can be determined algorithmically by software operating on a scanned image. Microfeatures at the character level include gradient (A) and contour (B).

Research



The Language Research group is developing interactive visualization techniques for procedural and object-oriented programs. Our tools allow the user to visualize clearly the run-time state of programs with recursion, higher-order functions, dynamic objects, inheritance, and so forth. A novel feature of the tools is that they support forward as well as reverse execution. They are a valuable aid for teaching and visual debugging.

Also in development is a novel object-oriented paradigm, called Constrained Objects (Cob), for compositional modeling of complex systems, especially engineering structures such as gears, trusses, and circuits. The environment provides tools for authoring the classes of constrained objects using a new variation of UML, called CUML (Constraint-based UML); visual interfaces that are customized to the application domain, translators for mapping diagrams into executable Cob programs, and a computational engine featuring constraint satisfaction, optimization, and relaxation for executing programs. Together, the modeling and execution tools offer an improved approach to computer-aided design and simulation.

Programming Languages

The field of programming languages is concerned with concepts, notations, methodologies, tools, and environments for the construction of robust, efficient, maintainable, and evolvable software. Researchers in this field are interested in paradigms such as object-oriented, concurrent, and declarative programming; domain-specific languages; distributed and network programming issues; methodologies for large-scale development of software; and formal foundations (semantics, analysis, verification, testing, etc.) for all aspects of software engineering and programming languages.

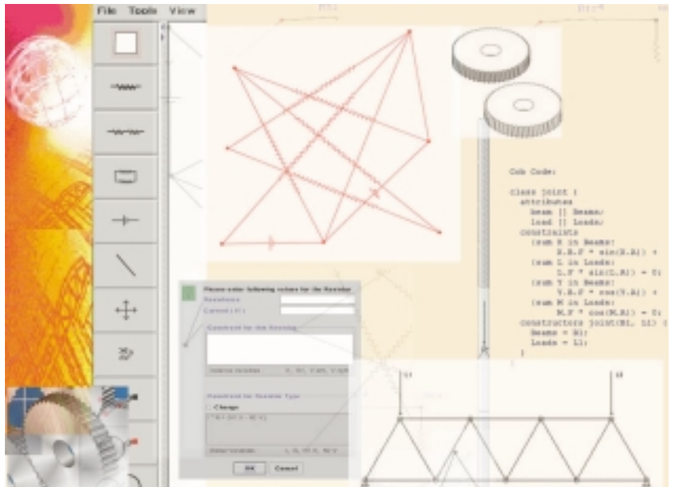
Faculty

- Bharat Jayaraman (Professor and Interim Chair)
- David Pierce (Assistant Professor)

Laboratories and Research Groups

Language Research Group
Director: Bharat Jayaraman
http://www.cse.buffalo.edu/LRG

The current focus of the group is on languages that support high-level, declarative, and visual modeling of complex systems. Research projects are in the areas of object-oriented modeling, constraint-based design, interactive program visualization, and domain-specific languages for applications in engineering and organizational modeling. In previous research, we have developed the theoretical foundations and experimental systems for a family of set-oriented programming languages.



The Constrained Object Modeling Environment

Computer Networks and Distributed Systems

Research in networks involves both hardware and software, and spans both user space and operating systems. Topics include wide-area networks and local-area networks, wired technology and wireless/mobile technology, data and telephony communications as well as integrated services, and applications (e.g., Web browsing) and modem access. Networking includes enabling technologies for other systems in distance learning, multimedia systems, distributed super-computing, telemedicine, collaborative research, electronic commerce, and online entertainment. Distributed systems is the study of the communication and coordination patterns of components found in networked computers.

Faculty

- Chunming Qiao (Associate Professor)
- Bina Ramamurthy (Teaching Assistant Professor)
- Victor Demjanenko (Adjunct Assistant Professor)

Laboratories and Research Groups

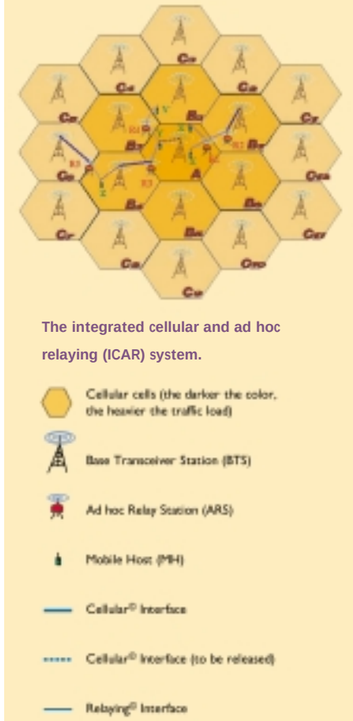
Laboratory for Advanced Network Design, Evaluation and Research (LANDER)

Director: Chunming Qiao
http://www.cse.buffalo.edu/~qiao

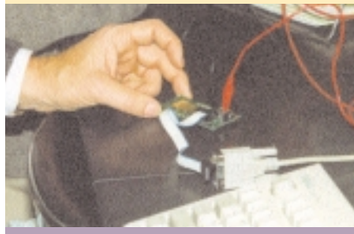
LANDER conducts research on networking architectures, protocols, network control and management issues, and performance evaluation. The lab focuses on the convergence of computer communications and telecommunications in WDM optical networks, mobile/wireless networks, the internet, and other technologies like ATM, parallel, and distributed processing. Active projects include optical burst switching for IP over WDM, protection/ restoration at the WDM layer, multicasting in WDM, next generation wireless systems, cellular and mobile ad hoc networks.

Distributed Systems Research Group
Director: Bina Ramamurthy
http://www.cse.buffalo.edu/~bina

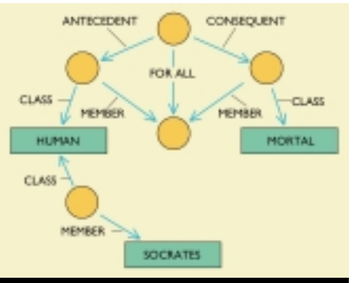
Current research involves peer-to-peer alternatives to traditional client-server models, ubiquitous computing with location-based services at the application program level, mining for patterns in wireless and web, performance analysis of component models in application servers, and adaptive interfaces for collaborative systems.



The integrated cellular and ad hoc relaying (ICAR) system.



Chunming Qiao is working on next generation wireless systems which integrated heterogenous wireless and mobile technologies. Here, a Bluetooth™ device is being tested in an effort to enable a pda, a cell phone, a laptop, and other ad hoc relaying devices to communicate seamlessly with each other.



A SNePS diagram representing the sentences, "Every human is mortal" and "Socrates is human." Using this diagram, the SNePS knowledge representation and reasoning system can infer that Socrates is mortal. Illustration from *Scientific American*, 1991.

Stuart C. Shapiro's primary research area is the computational understanding of human-level cognitive abilities, specifically the abilities that underlie natural-language use, reasoning, and rational acting. Shapiro conducts his research in conjunction with colleagues and students in the SNePS Research Group and in the Center for Cognitive Science. Their research is both theoretical and experimental, designing, building and using successive versions of the SNePS knowledge representation, reasoning, and acting system, and successive versions of Cassie, a computational cognitive agent implemented in SnePS.

Knowledge Representation/Reasoning and Computational Linguistics

Computational linguistics (or natural-language processing) and knowledge representation and reasoning are core areas of classical artificial intelligence (AI)—the computational understanding of human-level cognitive abilities. Knowledge representation and reasoning is the study of techniques for representing and reasoning about the information used by an AI program. Research at Buffalo is concerned with the abilities that underlie natural-language use, reasoning, and rational acting. We are interested in discovering how to build, and then actually building, a computerized rational agent—a computer system that can (1) converse in English about various everyday and specialized topics, (2) be taught about such subjects by instruction carried out in English, possibly with the aid of gestures, drawings, and diagrams, and (3) reason about those subjects, discuss them with humans, and perform as instructed.

Faculty

- Stuart C. Shapiro (Professor)
- William J. Rapaport (Associate Professor)
- David Pierce (Assistant Professor)
- Carl Alphonce (Teaching Assistant Professor)

Research Groups

SNePS Research Group (SNeRG)
Director: Stuart C. Shapiro
http://www.cse.buffalo.edu/sneps

Center for Cognitive Science
http://wings.buffalo.edu/cogsci/

PROJECTS

Belief Revision in a Deductively Open Belief Space
http://www.cse.buffalo.edu/sneps/snerg.prospectus

Contextual Vocabulary Acquisition
http://www.cse.buffalo.edu/~rapaport/role.pdf

An HPSG Natural Language Front End for SNePS
http://www.cse.buffalo.edu/~drpierce/research/sfy/

Identifying Perceptually Indistinguishable Objects
http://www.cse.buffalo.edu/sneps/snerg.prospectus

Intelligent Understanding of Computerized Patient Medical Records
http://www.cse.buffalo.edu/~rapaport/mednlp.pdf

Machine Learning Strategies for Parsing
http://www.cse.buffalo.edu/~drpierce/research/mlp/

SNePS-3
http://www.cse.buffalo.edu/sneps/snerg.prospectus

Electronic Commerce

Electronic commerce encompasses a broad range of issues including payment mechanisms, on-line markets, automatic negotiation, dynamic pricing, front-end and back-end management, intelligent agents, ontologies, information retrieval, security, trust, reputation, content monitoring, and on-line customer relationship management. E-commerce research at Buffalo concerns intelligent economic agents, that is, intelligent software agents that represent and act on behalf of their users in electronic markets. Our research draws on and brings together models and concepts from AI, multiagent systems, operations research, economics, and game theory.

Faculty

- Sviatoslav Braynov (Assistant Professor)

Decision Making in Adversarial, Competitive, and Cooperative Environments employs formalism for representing and reasoning with infinite hierarchies of beliefs. In adversarial environments (battlefields, markets, games, and so forth), an agent's optimal decision usually depends on what he believes the other agents will do, which in turn depends on what he believes the other agents believe about him, and so on. Such reasoning usually leads to an infinite loop: I think that you think that I think, and so on. The formalism developed by Dr. Braynov includes several methods for reducing the infinite regress of beliefs to a finite structure.

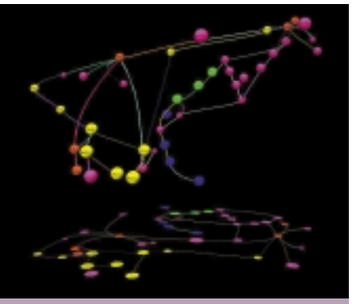
PROJECTS

http://www.cse.buffalo.edu/~sbraynov

Computational Model of Trust in E-commerce

Getting to Yes: A Model of Coherent Team Behavior

In the model, multiagent teams are represented as groups of agents capable of tolerating one another's misbehavior as far as this misbehavior does not threaten the overall group success. According to this view, teamwork is not just an ideal point of coherent behavior. It could be an evolving state where agents may gravitate around some steady performance. The model takes into account the fact that different agents may have different success rates and may face unforeseen contingencies in their activity. In order to allow for more flexible cooperation, agents are allowed to make uncertain commitments that is, instead of making 100% strong commitments, agents can make partial or variable commitments.



Real-life graphs can be quite complex. Ashim Garg is conducting research on visualizing a graph such that the users can easily understand the structure of the graph through its visualization. Shown here is a 3-D visualization of a graph depicting the history of UNIX. This visualization is constructed by Giotto3D, a software for visualizing graphs in three dimensions.

Information Visualization —Interactive cluster detection in multidimensional datasets http://www.cse.buffalo.edu/infoviz/datamining.html

KNOWLEDGE MEDIA LAB PROJECTS

Creating a Woman Friendly Environment for Learning IT

Using Technology to Improve Learning and Decrease Cost
http://pew.cse.buffalo.edu/

Community Linked Interdisciplinary Research
http://clir.buffalo.edu/

Researchers include Carl Alphonce, Philip Ventura, Helene Kershner, and Barbara Sherman.

Computer Vision and Information Visualization

Computer vision is an interdisciplinary field drawing on concepts from signal processing, artificial intelligence, neurophysiology, and perceptual psychology. The primary goal of computer vision research is to endow artificial systems with the capacity to see and understand visual imagery at a level rivaling or exceeding human vision. One part of research at UB focuses on computational theories for contour image analysis of things such as technical drawings, architectural plans, maps, and even cartoons to enable such images to be used in human and computer interaction. With psychophysical experiments, aspects of contour images of perceptual significance to humans are identified.

Active foveal vision explores the use of cameras whose resolution decreases from center to periphery of the field of view, similar to the human retina. This research focuses on the design of computer chips to implement a system that registers a central region of interest with high detail while displaying a larger zone at lower resolution, and on the algorithms that permit variable resolution image sequences to be understood.

Our fundamental research includes developing techniques for visualizing common data-structures such as graphs and multidimensional data sets, and visualizing molecular structures. Our applied research includes visualizing data from practical applications, such as bioinformatics, software engineering, pharmacokinetics, engineering and design, bioimaging, and digital art.

Knowledge Media Lab
http://kml.cse.buffalo.edu/kml/

Faculty

- Deborah K. W. Walters (Associate Professor)
- Peter Scott (Associate Professor)
- Ashim Garg (Assistant Professor)

VLSI, Computer Architecture, and Security

Hardware and software issues from the circuit to the system have three main foci: Very Large Scale Integration (VLSI) circuits and systems, computer architecture, and computer security. VLSI includes circuits and systems design, systems on chip, testing, computer-aided design and synthesis. Computer architecture deals with the study and design of computer systems to meet functional, cost, and performance requirements of applications. Computer security research focuses on information survivability techniques such as intrusion detection, assessment and recovery in networked computers and mobile codes. Assessment of performance, reliability, availability, and security is a key step in the design, analysis, and redesign of computer systems.

Faculty

- Ramalingam Sridhar (Associate Professor)
- Shambhu Upadhyaya (Associate Professor)
- Nihar Mahapatra (Assistant Professor)

Laboratories and Research Groups

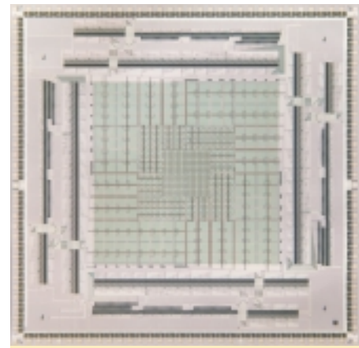
High Performance VLSI Systems and Architecture Laboratory (HPVSA)
Director: Ramalingam Sridhar
http://www.cse.buffalo.edu/~rsridhar/hpvsa.html

Research in the HPVSA laboratory focuses on high-performance (low power and high speed) VLSI circuits and systems design, special purpose VLSI architecture with applications to image and signal processing, multimedia systems, and embedded systems design.

Computer Architecture and VLSI Research Group
Director: Nihar Mahapatra
http://www.cse.buffalo.edu/~mahapatr

Security, Privacy and Dependability Research (SPIDER) Group
Director: Shambhu Upadhyaya
http://www.cse.buffalo.edu/~shambhu

Electronic Test Design Automation Lab
http://www.cse.buffalo.edu/news/ibm_lab_2001.html



Collaborations bring innovative results —this foveal vision sensor is a project of the VLSI and Computer Vision groups.

PROJECTS

http://www.cse.buffalo.edu/~shambhu/research.html

Defect Analysis of Multiport Memories and New Fault Models

Testing and Diagnosis of System-on-Chips

Bandwidth Reduction, Fault Tolerance and Recovery in Video-on-Demand Systems

Self-Verifiable Enterprise Server Design

Routing and Reconfigurability in Mobile Ad-hoc Networks

A Distributed Concurrent Intrusion Detection Scheme Based on Assertions

Secure and Fault Tolerant Voting in Distributed Systems

Secure Communication in PCS and Mobile Environment

Research Sponsors

Alcatel USA

Argonne National Laboratories

Booz Allen & Hamilton

Calspan/UB Research Center

Hewlett Foundation

IBM Corporation

Intel

Internal Revenue Service

Lockheed Martin

NASA

National Institute of Justice

National Institutes of Health

National Science Foundation (ITR, IGERT, CAREER, CISE, ROLE)

Nokia

Nortel Networks

Northrop Grumman Amherst Systems

New York State Office of Science, Technology, and Academic Research

Oishei Foundation

Pew Education and Technologies Fund

SGI

Siemens

Telcordia

United States Postal Service

US Air Force Office of Scientific Research

US Army Communications and Electronics Command (CECOM)

US Defense Advanced Research Projects Agency

US Department of Defense

US Department of Energy

Corporate Partners

IBC Digital

IBM Corporation

Kodak

Myricom

Nortel Networks

Praxair

Q-Chem

Sarnoff

SGI

Sun Microsystems

Veridian Engineering Division

Xerox

Tours and Demonstrations We welcome visitors from the technical community, educational institutions, and the general public who are interested in our research. The Center for Computational Research holds frequent tours of their facilities, and CEDAR welcomes visitors by appointment. Demonstrations of the department's research are arranged as needed. Contact the Executive Officer at (716) 645-3180 x 105, or write cse-info@cse.buffalo.edu if you are interested in a tour.

Media Contacts Members of the broadcast and print media who are interested in our Department's research should call the Chair or the Executive Officer, (716) 645-3180 x 105, and can also write cse-info@cse.buffalo.edu.

Recent Ph.D.s

Pavan Aduri
Average-case complexity theory and polynomial-time reductions (2001)

Sung-Hyuk Cha
Use of distance measures in handwriting analysis (2001)

Kevin P. Chugh
An object-oriented approach to physically-based human tissue modeling for virtual reality applications (2001)

Chun-Hsi Huang
Graph algorithms on coarse grained parallel computers (2001)

Krassimir Ianakiev
Organizing multiple experts for efficient pattern recognition (2000)

Haythem Ismail
Reasoning and acting in time (2001)

Myoungki Jeong
Multicast in optical burst switched WDM networks (2001)

Minchul Jung
Font classification and character segmentation in postal address interpretation (2001)

Hui Luo
Knowledge-based image understanding and indexing system for medical image databases (2001)

Markus Mielke
Transmission support for interactive distributed multimedia presentation systems (2000)

Yousong Mei
Cost effective design of WDM optical networks for static and dynamic traffic (1999)

Elyse Milun
Algorithms for stylus generated images inspired by the human visual system (1999)

Aibing Rao
An integrated theory of image database modeling, indexing, and content-based retrieval (2001)

Gholamhosein Sheikholeslami
Multi-resolution content-based image retrieval and clustering in large visual databases (1999)

Kris Schindler
An energy efficient design methodology for combinational logic circuits (2001)

Myungsik Yoo
Optical burst switching for the next generation optical internet (2000)

Dantong Yu
Multidimensional indexing for large-scale databases (2001)

Sujit T. Zachariah
Algorithms for efficient extraction of faults in large VLSI circuits (2000)

Xijun Zhang
Traffic grooming and scheduling, wavelength routing and assignment, and multicast in WDM networks (1999)

Lei Zhu
Keyblock: an approach for content based image retrieval (2001)

All Ph.D. dissertations and other technical reports can be downloaded from http://www.cse.buffalo.edu/tech-reports/

Activities of Interest to Industry

Short Course Program

The department offers short courses at company sites. Courses are tailored to meet the needs of growing and start-up companies. The areas offered change in response to market forces, and include object oriented analysis and design, operating systems, and a wide range of programming languages. Hands-on and team-based learning is emphasized.

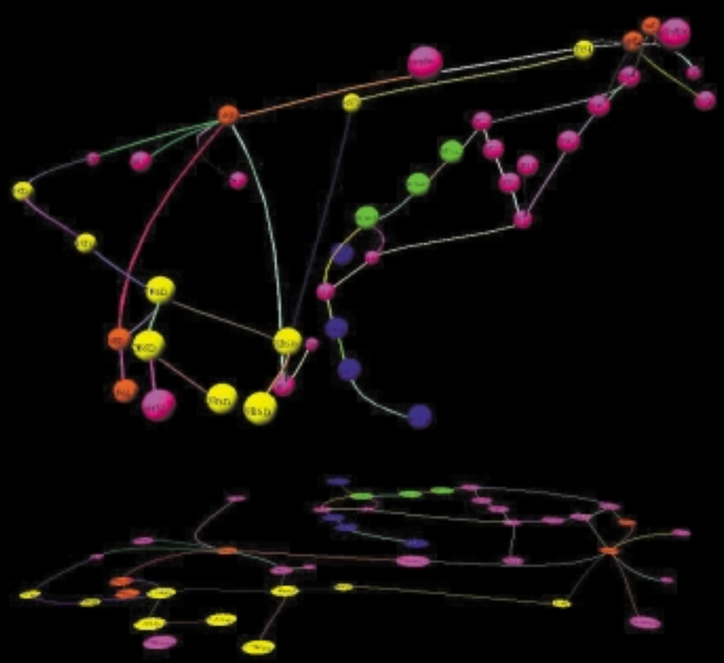
CSE Faculty: A Regional Resource

Computer Science & Engineering at the University at Buffalo provides the expertise of our faculty and associated researchers to programmers and other IT specialists. The faculty and staff at the Department of Computer Science and Engineering have research expertise in the following areas:

- Linux
- Data Mining
- Security
- Databases
- Visualization
- High Performance Computing
- Machine Vision and Image Processing
- Rapid Software Prototyping
- Multimedia and Digital Libraries
- Biomedical Computing and Informatics
- AI/Robotics

Three of our teaching faculty
Top to bottom:
Barbara Sherman
Carl Alphonce
Phil Ventura

Information visualization is a good example of the interplay of theoretical and applied research. Fundamentally, robust work in algorithms can provide entirely new techniques as in this example, where history is graphed in three dimensions. Each colored ball represents a historical moment in the development of Unix, but the interplay of these events is more authentically graphed as a joining of elements, rather than a progressive linear series with implied irreversibility. At the same time, such innovative visualization of graphs permits development in applied fields, for enhanced graphical user interfaces, and visualization of data from practical applications.



Labs, Equipment, and Facilities

Facilities Available:
The Department's research facilities include more than 100 Sun Workstations as well as X-terminals and SPARC-server systems, including four Ultra60/2360s, three Ultra Enterprise 450s, and several Ultra 10s, totaling 800 gigabytes of disk space. Two Sun Ultra 80s, with four CPUs and four gigabytes of memory each, handle computer-intensive processing. Power Macintoshes, Windows NT machines, and laser printers are readily available. The Department has SGI Onyx and SGI Octave machines. The Department also has access to computing facilities provided by the University and Science and Engineering Node Services (SENS), including a Sun time-sharing system and workstations. The Center for Computational Research is a supercomputing center, with an SGI Origin2000 and IBM SP2. The Department's systems are connected to the University backbone by a 100-Mbps Ethernet port directly on a gigabit router. The Department's internal networking is a mix of 100BaseT, switched 100BaseT, and Gigabit Ethernet. Through NYSERNet, the University has an FDDI link to a SprintNet T3 connection to the Internet and to Internet2. Dial-up access, including PPP, is available.

CEDAR Infrastructure
Connected to the Internet with high-speed T3 and I2 links, CEDAR's network backbone is a 1.2 Gigabit/sec Cisco Catalyst 5000 Switch feeding five Fast Ethernet 3Com LinkSwitch 1000s. CEDAR also has 56kb modems for PPP dial-up access. A dedicated T1 line runs from CEDAR to the USPS engineering facility in Merrifield, VA.

UNIX Workstations include 180 Sparc Stations, a UltraSparc Enterprise server E450 with 1GB of main memory, four SparcServer 1000s, three Sun Ultra 2 workstations, three Sun Ultra 1 workstations, eight Sun Ultra 10 workstations, five SparcStation 20 model 712, three Sparc 20 model 612, 12 Sparc 10s (four model 60, two model 50, six model 30; the models in the Sparc 10s vary by CPU clock speed) seven Sparc 5s, five Sparc 4s, 32 Sparc 2s, and one SparcStation Voyager.

CEDAR has a four processor Digital AlphaServer 4100 with 1GB of main memory and 20GB of disk space for really CPU-intensive tasks, like compressing the Postal Databases, and other projects.

There are four flatbed scanners, three digital tablets, and one Image Lift. Image Lift is a CEDAR-developed, custom-designed, high-speed mail piece transport that is used to gather gray-scale images of mail pieces at a rate of 12 pieces/sec at a resolution of 300 dpi.

CSE Database and Multimedia Research Lab
Various configurations are in review to provide a total of 20 TB of on-line storage in a scalable storage area network (SAN), the major element of the MultiStore project. The SAN connects to the compute server facilities using fiber channel—arbitrated loop (FC-AL) giving high band width access to data and metadata.

Patricia James Eberlein Memorial Graduate Lab
Three Sun Ultra 10 workstations with high-end Elite3D-m3 graphics, 16 Sun Ultra 5 workstations, one SGI O2, three NT workstations, and one HP 8000TN LaserJet printer with duplexer make up the resources of this student lab.

CSE Teaching Assistants each have an X-terminal or Workstation on the desk in their office.

Security, Privacy, and Dependability Research (SPIDER) Lab
The servers for the Graduate and Research systems include a Sun Ultra 60 Model 2360, 512Mb memory, 230Gb disk space; a Sun Ultra Enterprise 450 Model 4400, 4Gb memory; and a Sun Ultra Enterprise 80, 4GB memory server as the batch compute server.

LANDER (Lab for Advanced Network Design, Evaluation and Research)
The lab has a dozen Pentium III- and IV-based workstations running Windows and Linux in addition to several Sun Ultra workstations running Solaris. Licensed software tools like CPLEX and OPNET and free software tools like NS2m GlomoSim and Yacsim are available.

Electronic Test Design Automation Lab
Originally opened in May, 1999, the facility now includes three IBM RS6000 PowerServers, 14 RISC PowerPC Clients, and several IBM Electronic Design Automation (EDA) tools, including LogicBench, CircuitBench, and TestBench EDA applications. The increased capability provides hands-on access to VLSI design and test applications to over 150 university students and faculty for VLSI related course work and research activities.

Our Region

Niagara Falls is a perennial favorite for visitors to both the Canadian and American sides.

Buffalo, New York, is the commercial hub of a binational region that is home to 2 million people. The region includes the eight counties of western New York State and the Niagara peninsula of Ontario, Canada. A deep history and a medium population density mean that the region offers attractions and advantages usually only available in larger communities.

Summer season activities are sailing, hiking, camping in the nearby Allegheny national forest and 15 provincial and state parks of the region. Winter activities are skiing, skating, and ice fishing. An abundance of natural resources, including two Great Lakes, Niagara Falls, and a varied countryside lend beauty and a unique sense of place. Sports spectators will enjoy the Buffalo Sabres (hockey), the Buffalo Bills (football), baseball's AAA Bisons, the Buffalo Blizzard (indoor soccer), and the Buffalo Destroyers (arena football). The University at Buffalo is a participant in Division 1 football and other intercollegiate sports for men and women.

A wide range of residential choices is available. Victorian urban homes, elite suburban architecture, town homes, rural living, and riverside properties are all available within 30 minutes of the UB campus. Computer Science and Engineering is located on UB's North Campus in Amherst, New York. The campus is a self-contained, safe, and friendly place where many researchers and students work comfortably in the evening hours. All computing facilities, labs, and offices in Computer Science and Engineering are open 24 hours a day for users with appropriate access permission.

Buffalo has a symphony, a ballet company, and numerous modern and ethnic dance companies. Excellent restaurants are numerous. The Albright-Knox Art Gallery has a rich permanent collection and larger visiting blockbuster shows. Other galleries, including the Marion Anderson Gallery and the Burchfield-Penney Art Gallery are inspirational to a fine arts community. Buffalo's industrial and residential architecture is famous—Kleinhans Music Hall designed by Saarinen, several Frank Lloyd Wright houses, and early 20th century high-rise and industrial architecture are notable.

The region is traditionally part of the manufacturing belt of the Midwest, and now has a growing economy in medicine, high technology, and communications. Today, the region lures an ethnically diverse population. There are active cultural and religious communities from around the globe, and an atmosphere of appreciation and respect for diversity. UB is a strong leader in the Western New York community.

Buffalo has a vibrant theater district offering new work, classical theater, and Broadway productions.

University at Buffalo is a member of the Association of American Universities.

Intercollegiate sports contribute to "big school" spirit; professional sports draw many fans to games.

The region's economy combines agriculture, industry, commerce, medicine, education, and tourism.

The Albright-Knox Art Gallery contains the best modern collection outside New York City.